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SILVICULTURAL SYSTEMS

BY

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PREFACE

THE lack, in the English language, of any comprehensive work on silvicultural systems is a sufficient reason for devoting to this important subject the first of a series of manuals dealing with different branches of forestry, which will appear from time to time.

Forestry is now passing through a critical stage. The depletion of natural forests that has taken place during the past hundred years in many parts of the world gives genuine cause for alarm, and steps have been taken in many countries to conserve and protect at least some small proportion of their original forest area. This, however, is only an initial step; if the problem of future timber supplies is to be solved, it is also of the utmost importance that the reduced forest area now available should be treated in such a way as to produce the highest possible sustained yield of suitable timber compatible with economic and other considerations. Certain European countries were faced with this problem centuries ago, and as a result of long experience have evolved methods of treatment, termed 'silvicultural systems', which are an object-lesson to the whole world. The detailed study of these systems under as many different conditions as possible is the only means of acquiring that special knowledge which will lead to their intelligent application in practice.

Lest it may be held that systems which have been evolved in Europe are not applicable to other parts of the world where totally different conditions prevail, the fact may be mentioned that for more than fifty years past the silvicultural systems of Europe, with suitable modifications, have been applied successfully in many parts of India under a variety of conditions and in many types of forest; and it may be truly said that the great progress which forestry has made in that country during the past half-century has been due to a large extent to the fact that the officers of the higher branch of the Forest Service have received their practical training in the forests of continental Europe. The close study of European systems does not imply that they should be followed slavishly under all conditions; a proper understanding of these systems, however, is an essential preliminary to their adoption in such modified form as may be indicated by local conditions. In Great Britain the successful application of some of the systems would be impossible at present for two reasons: in the first place many British woodlands are in a derelict state through faulty treatment, and in the second place the country

is so infested with rabbits that economic forestry in any form is often difficult if not impossible. If the rabbit scourge were eliminated and the woodlands were brought into a better condition, there would be no reason, in so far as soil, climate, and other factors are concerned, why the silvicultural systems of continental Europe should not be practised in Great Britain with results far more satisfactory from the economic point of view than those attained under the methods so frequently practised hitherto.

In preparing this book every endeavour has been made to elucidate principles by giving a sufficiency of actual examples, while avoiding a superfluity of local detail which might tend to confuse the reader. The plan has therefore been followed of explaining the systems on general lines and giving only a few local examples to illustrate important or special points. The historical information given is necessarily brief, but it may prove of interest in throwing light on the influences under which systems have been evolved, developed, and in some cases superseded. French and German terminology has been given with the object of assisting those conversant with these languages who may wish to study the literature or visit the forests of continental Europe.

The application of silvicultural systems presents problems of an essentially practical kind; hence the descriptions and discussions in this book have been based as far as possible on the results of personal investigations extending over a number of years in the forests of several different European countries. Apart from this, experience gained in India has proved invaluable in helping towards the appreciation of the more important points connected with the introduction and practice of silvicultural systems under conditions often very different from those prevailing in Europe. Although every endeavour has been made to describe the various systems as they are actually practised, and the descriptions have been supplemented by photographs taken personally in different countries, the reader is asked to regard this book not as a means of acquiring a complete knowledge of silvicultural systems, but rather as a guide towards the practical study of systems in the forest.

R. S. T.

Oxford,

14*th January* 1928.

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I

INTRODUCTION

A *silvicultural system* may be defined as the process by which the crops constituting a forest are tended, removed, and replaced by new crops, resulting in the production of woods of a distinctive form. In this definition tending refers mainly to thinning operations carried out in immature woods, in so far as these operations affect the state of the crop and soil at the time of regeneration.

A silvicultural system embodies three main ideas: (1) the method of regeneration of the individual crops constituting the forest, (2) the form of crop produced, and (3) the orderly arrangement of the crops over the forest as a whole, with special reference to silvicultural and protective considerations and the economic utilization of the produce.

A study of silvicultural systems presupposes a knowledge of the principles of silviculture, while the application of these systems in practice is closely connected with the requirements of forest management.

Forest management teaches us the great economic advantage of regular sustained yields over intermittent or spasmodic yields. With the object of ensuring future sustained yields the ideal of the normal forest has been created. Such a forest contains a regular and complete succession of age-classes from the youngest to the oldest; the several age-classes are represented in correct proportion, density, and distribution, so that as each becomes ripe for felling it may be cut in its proper turn and regenerated, and the outturn will be equal each year or period of years so long as the normal state of the forest is maintained. The normal forest can hardly be said to exist in reality; rather it should be regarded as an ideal to be aimed at, and approached as nearly as possible, in any scheme of forest management aiming at sustained yields.

Since the practical application of silvicultural systems is closely connected with the requirements of forest management, the ideal of the normal forest has to be kept in mind in applying a silvicultural system to any regulated scheme of management which aims at this ideal. In the application of a silvicultural system to such a scheme there are two main aspects to consider : (1) the general framework of the scheme, including the division of the area, the allotment of areas for felling, and the regulation of the yield; these

are essentially questions of forest management, and do not concern us here except in so far as they may affect questions of silviculture, protection, and economic utilization; (2) the technique of the system itself, including the conduct of fellings, regeneration, and tending operations; it is with the latter that we are primarily concerned.

Various classifications of silvicultural systems have been proposed. If we take into consideration all the variations of treatment that are in use at the present day or have been practised in the past, there is scarcely any limit to the number of these variations. It is therefore necessary to group the various forms of treatment into what may be termed main systems, and to devise a general classification of these. Opinions differ considerably as to how such a classification should be made, but for our purpose the following will be suitable:

I. High Forest Systems. Crops normally of seedling origin.

A. Felling and regeneration for the time being concentrated on part of the forest area only:

1. Old crop cleared by one single felling: resulting crop even-aged.—*Clear-cutting system.*

2. Systems of successive regeneration fellings.[1] Old crop cleared by two or more successive fellings: resulting crop more or less even-aged or somewhat uneven-aged:

(*a*) Regeneration fellings distributed over whole compartments or sub-compartments:

i. Opening of canopy even: young crop more or less even-aged and uniform.—*Uniform system.*

ii. Opening of canopy by scattered gaps: young crop more or less even-aged.—*Group system.*

iii. Opening of canopy irregular and gradual: young crop somewhat uneven-aged.—*Irregular shelter-wood system.*

(*b*) Regeneration fellings confined to certain portions of compartments or sub-compartments at a time:

i. Fellings in strips.—*Strip systems* (various).

ii. Fellings beginning in internal lines and advancing outwards in wedge formation.—*Wedge system.*

B. Felling and regeneration distributed continuously over the whole area: crop wholly uneven-aged.—*Selection system.*

[1] *Shelter-wood systems* is a general term which comprises systems under A 2 and B.

C. Accessory systems, arising out of other systems:

1. Form of forest produced by introducing a young crop beneath an existing immature one.—*Two-storied high forest.*
2. Form of forest produced by retaining certain trees of the old crop after regeneration is completed.—*High forest with standards.*

II. Coppice Systems. Crops, in part at least, originating from stool shoots (coppice) or by other vegetative means:

A. Crop consisting entirely of vegetative shoots:

1. Crop removed by clear-felling, even-aged.—*Coppice system.*
2. Only a portion of the shoots cut at each felling: crop uneven-aged.—*Coppice selection system.*

B. Crop consisting partly of vegetative shoots, partly of trees, generally of seedling origin.—*Coppice with standards system.*

II
THE CLEAR-CUTTING SYSTEM

Fr. *Procédé par coupe unique, Coupe blanche, Coupe à blanc étoc, Coupe rase.* Ger. *Kahlschlag, Kahlhieb, Platthieb* (not in common use).

1. GENERAL DESCRIPTION

Under this system successive areas are clear felled and regenerated, most frequently by artificial means but sometimes naturally. As a general rule the clearing of a coupe should be complete, although pre-existing poles and saplings may be left if they occur in promising groups large enough to form self-contained crops. Under ordinary conditions, however, isolated poles and saplings should be removed, as these are likely to develop into branchy trees as well as to interfere with the new crop.

On the other hand it may be necessary in special cases to introduce nurses to assist in the establishment of the new crop: in some of the high moors of Bohemia, for instance, spruce regenerated artificially on clear-cut areas cannot withstand the severe frosts without the aid of temporary nurses, such as birch and mountain-ash, which appear naturally or are introduced artificially. It is sometimes customary, especially in the tropics, to kill unmarketable trees by 'ringing' or 'girdling' and to leave them standing in order to save the cost of felling them.

All timber and other marketable material should be removed at once, and if the debris remaining is likely to interfere seriously with sowing or planting, or with the establishment of the new crop, it should be burnt.

2. SIZE, FORM, AND ARRANGEMENT OF COUPES

General Considerations. In its ideal form the clear-cutting system involves felling and regenerating each year equal areas (coupes) on which the stands have reached the predetermined age of maturity (rotation). If this process is repeated each year for the whole rotation and no accidents have happened to interrupt the continuity, a normal series of age gradations, aged 1, 2, 3 . . . r years (r being the number of years in the rotation), will have been established. Where the quality of the soil varies appreciably from place to place, coupes not equal in area but equiproductive are formed, those on the poorer soils being larger than those on the more fertile soils.

In point of fact the ideal form of clear-cutting system, involving the felling and regeneration of equal annual coupes and the formation of an uninterrupted series of age gradations, has been found impracticable in high forest except under very favourable conditions. Modelled on the coppice system, it was introduced in the coniferous forests of Germany at the end of the eighteenth century, but proved a complete failure owing to the impossibility of maintaining the ideal regularity aimed at; the longer the rotation the more difficult it became to fulfil the aim. For this reason the modification of periodic instead of annual coupes was adopted in Germany at the beginning of the nineteenth century. Under this modification it may be arranged, for instance, to fell and regenerate an area ten times that of the theoretical annual coupe in a period of ten years, the actual area felled annually varying from year to year within this period. Such a procedure is indicated where considerable latitude is desired for economic reasons, or where natural regeneration from adjoining woods is relied on, or where artificial regeneration is carried out but supplies of seed or plants are obtainable only at irregular intervals.

The size, form, and arrangement of the coupes vary greatly according to local conditions and requirements. Where damage from wind, frost, insects, erosion of hill-sides or other dangers is not to be feared, the coupes may be of any size or shape compatible with local topography, means of extraction and transport, and other considerations; but in certain cases special measures may be necessary.

Protective Measures. A protective measure sometimes adopted against frost, snow, drought, cold winds, and other dangers, is to make within a mature crop small scattered coupes which are usually regenerated artificially. Further coupes are made from time to time in the remaining portions of the mature crop until the whole area has been felled and regenerated. As a means of introducing sensitive species or of producing somewhat uneven-aged crops, this procedure has its merits, but it is somewhat difficult to control and is expensive to operate, owing to the scattered nature of the fellings; it also increases danger from wind, while on steep hill-sides damage is liable to be caused to groups of young growth by the sliding of timber during extraction. Hence where protective measures are required, it is preferable to adopt the procedure followed in countries like Saxony, where clear cutting has been systematized in the manner described below with the view of preventing damage by storms, cold winds, frost, drought, insects, and timber extraction.

Where damage by storms is to be feared, care is necessary to

avoid cuttings which will suddenly expose the interior of a wood to the prevailing storm direction, which in northern and central Europe is from the west or south-west. Trees grown from youth upwards in a crowded state develop long boles, small high crowns, and feeble root-systems; if such trees are exposed to the force of a strong wind, the lateral pressure of the wind on the crown, acting at a considerable distance from the ground, exercises a leverage which the feeble root-system cannot always withstand, and the tree is uprooted, or, failing this, the bole may snap across at some point of weakness. For this reason, in regions subject to storms the coupes should be so arranged that fellings in successive adjacent areas proceed against the prevailing storm direction, that is, in Europe from E. to W., or from NE. to SW., with local diversions in hilly country. By this arrangement there is always a sheltering wood, or failing this there should be a good shelter-belt, to windward of the coupe felled. The usual procedure, therefore, is to select areas containing woods which will come under the axe for a limited period ahead, say 20 years, and arrange the coupes in those areas in such a way that fellings proceed against the storm direction. A further precaution is to form narrow coupes approximating to cleared strips running at right angles to the storm direction, and to avoid anything in the nature of large clearings. In the spruce forests of Saxony these coupes vary from about 20 to 100 yards or more in breadth. Such strip-like fellings have been practised for centuries in Central Europe, and are the most suitable form of clear fellings in mountainous country.

Risk of damage by insects may further complicate the arrangement of fellings. For example, a special arrangement of fellings is adopted in many pine and spruce forests in Europe as a protective measure against the pine weevil, *Hylobius abietis*, Fabr. This insect lays its eggs in the stumps and roots of felled trees, where the larvae feed innocuously. The perfect beetle inflicts great damage on young coniferous plants, chiefly Scots pine and spruce up to 6 years of age, by gnawing the bark of the stem and frequently killing the plant outright. Among measures adopted to check the multiplication of these insects are (1) the formation of small coupes, and (2) the avoidance of fellings in contiguous areas except after the lapse of some years; in the spruce forests of Saxony the interval varies from 5 to 10 years. This formation of small segregated coupes was based on the supposition that the insect was almost incapable of flying, and could only crawl slowly, its radius of activity being very restricted in consequence. The investigations of Munro in Great Britain, however, have shown that the beetle is capable of travelling

to much greater distances than was at one time supposed, and that although the formation of small segregated coupes is a good precautionary measure, it is effective only if accompanied by the constant trapping of beetles before, during, and after the fellings.

Cutting Sections. In order to facilitate the formation of small or narrow coupes and their arrangement in some regular order, it is usual to divide each main unit of the forest into a number of cutting sections.[1] These may be defined as units, usually of limited size, formed for some special purpose (not necessarily the purpose with

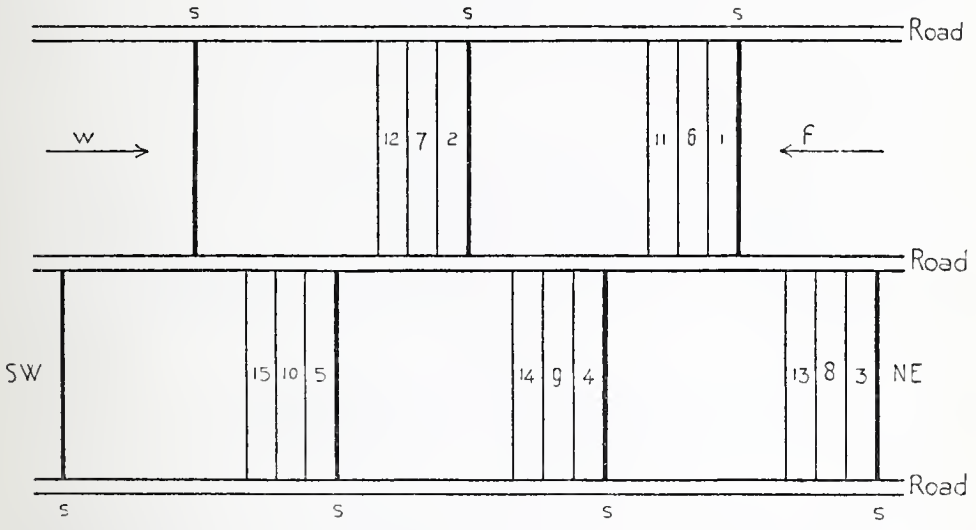

FIG. 1. Clear-cutting system on level ground. Diagrammatic representation of an area divided into 5 cutting sections, showing arrangement of coupes to provide for (1) cutting against storm direction, (2) intervals of 5 years between successive fellings in adjoining coupes, (3) direct access from coupes to roads. Numbers denote years of felling. *s*, *s*, severance cuttings ; *f*, felling direction ; *w*, wind direction.

which we are concerned here). Within each cutting section the coupes are arranged in such manner as will meet the necessities of the case. Figs. 1 and 2 show how coupes may be arranged in cutting sections so that the general direction of felling is from NE. to SW. against the prevailing storm direction, while at the same time intervals of 5 years are allowed for between successive fellings in adjacent coupes. Narrow coupes arranged in this way also serve as a protection against frost and cold NE. winds. In Saxony the tendency in recent years has been to alter the felling direction to one of N.–S. in places where frost damage is severe, and in fact to adopt

[1] These are sometimes termed 'cutting series' but it is preferable to use the term 'series' (Fr. *série*) to denote a unit comprising, ideally, a complete series of age-gradations from 1 to *r* years: a cutting section will then be a subdivision of a series.

the clear strip system (see p. 103). Wherever possible, cutting sections should be bounded on the windward side by shelter belts of low-branching trees. Where permanent cutting sections are laid out, roads and rides bordered by such trees make the best boundaries.

In the formation of cutting sections it may be necessary to divide existing woods into two or more parts. If this can be foreseen long enough ahead, wind-belts of low-branching trees may be produced by making 'severance cuttings'. These are cleared lines of varying breadth, usually 30–50 feet, cut through the wood while it is still comparatively young in order to induce low branching by the border trees (see Fig. 2). Severance cuttings, which run more or less at right angles to the prevailing wind direction, may be used as roads or rides, or may be planted up.

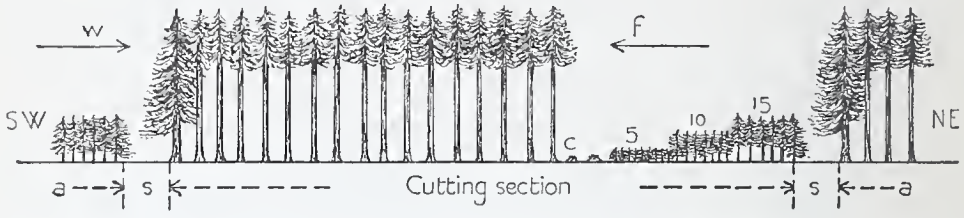

FIG. 2. Clear-cutting system. Longitudinal elevation of a single cutting section. Numbers denote ages of crops. *s,s*, severance cuttings ; *a,a*, adjoining cutting sections ; *c*, coupe of the year ; *f*, felling direction ; *w*, wind direction.

In order to facilitate extraction of timber, where the nature of the ground allows of it the cutting sections should be bounded by roads running along the narrow ends of the coupes as shown in Fig. 1 ; in Saxony this is a common arrangement on more or less level ground, where the main extraction roads run parallel to each other in a general NE. to SW. direction.

The length of a cutting section may vary considerably. In the Tharandt School Forest in Saxony cutting sections generally extend over two compartments, and have an average length of about 600 metres, with a maximum of over 1,000 metres. The modern tendency, however, is to decrease the size of cutting sections in order to provide mobility in the working.

Form and Arrangement of Coupes in Hilly Country. In hilly country considerations of protection against storms and insects should be combined with measures of protection against damage to young crops through the sliding of timber down the slopes. In such country the prevailing winds tend to become diverted according to the trend of the valleys, and the local wind direction has to be studied. The coupes themselves are generally long and narrow, and are

arranged in one of two ways, (1) with the long axis running up and down the slope and the fellings proceeding against the local storm direction, and with a road running along the lower edge of the cutting section (see Figs. 3 and 5), and (2) with the long axis running more or less contourwise, but slightly inclined to the hori-

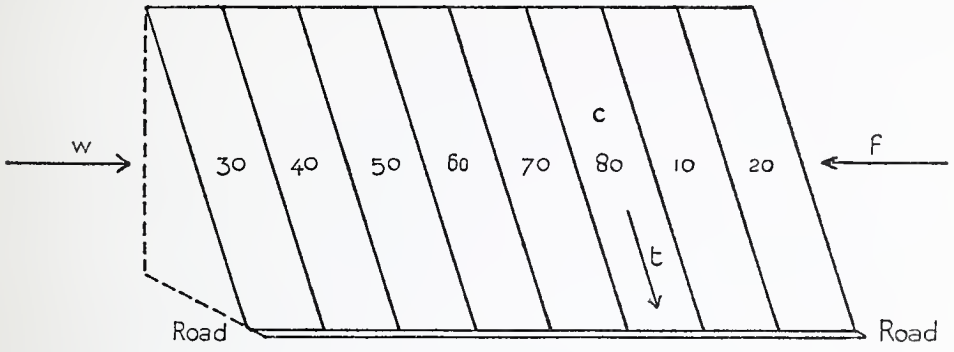

FIG. 3. Diagrammatic representation of clear-cutting system in hilly country, showing a cutting section with vertical coupes with successive cuttings at 10-year intervals arranged against the prevailing wind direction. Numbers denote ages of crops. Rotation 80 years. *c*, coupe of the year; *f*, felling direction; *t*, direction of timber extraction; *w*, wind direction.

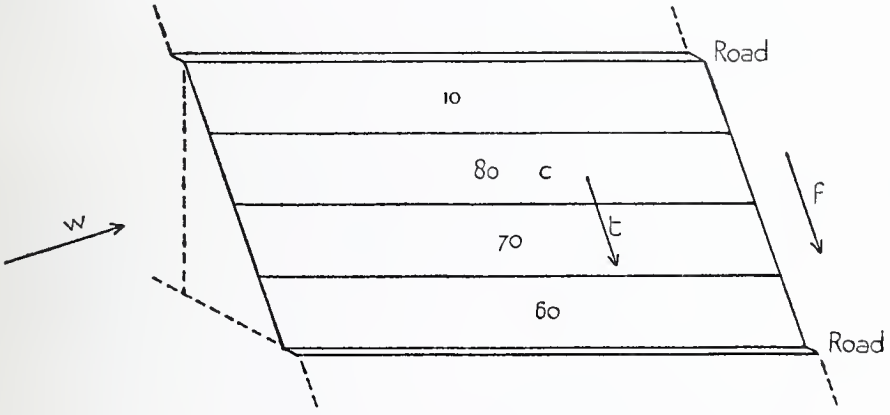

FIG. 4. Diagrammatic representation of clear-cutting system in hilly country, showing horizontal coupes with successive cuttings at 10-year intervals arranged in a downhill direction in a short cutting section to prevent damage to young crops by the sliding of large timber. Numbers denote ages of crops. Rotation 80 years. *c*, coupe of the year; *f*, felling direction; *t*, direction of timber extraction; *w*, wind direction.

zontal if this is necessary in order to avoid exposing unprotected woods to the prevailing winds; the cutting direction is downhill (see Fig. 4). Under the latter arrangement short cutting sections are necessary, bounded by graded roads at fairly frequent intervals, in order that large timber may not have to be slid down through young woods.

3. CLEAR-CUTTING WITH ARTIFICIAL REGENERATION

General Procedure. Under the clear-cutting system artificial regeneration is far more commonly practised than natural regeneration, planting being more general than direct sowing in temperate countries; patch sowing of Scots pine, however, is not unusual in France, while oak is regenerated by direct sowing of acorns in various parts of Europe. As a rule it is important that sowing or planting should be carried out as soon after the felling as possible: cleared areas left for a year or more tend to become covered with weeds and regrowth, and the soil deteriorates, dry soils becoming drier on the surface, and wet soils becoming more swampy.

Artificial Regeneration with the Aid of Field Crops. (Fr. *Cultures intercalaires, culture sylvicole et agricole combinée.* Ger. *Waldfeldbau, Baumfeldwirtschaft, Brandwirtschaft.*) Under this special form of artificial regeneration, field crops are cultivated temporarily on the cleared coupes for one or more years, the sowing or planting of the tree species being carried out before, along with, or after the sowing of the agricultural crop. This practice, which varies greatly in detail, has long been in force in parts of Germany, and was much in vogue in Finland until last century. In the Spessart and in Hesse-Darmstadt there are some excellent stands of oak, the oldest dating from 1813, raised by sowing acorns along with cereal crops (see Fig. 64). In Hesse-Darmstadt the regeneration of Scots pine is carried out to the present day along with the cultivation of potatoes. This may be seen typically on the sandy tracts in the neighbourhood of Darmstadt, where the stumps are dug up, the soil is worked, pine seedlings one year old are planted in lines in April, and potatoes are put in between the lines of pine seedlings in May (see Fig. 68). The importance of potatoes in the food-supply of Germany is so great, that even where their cultivation in this manner is scarcely remunerative the practice is continued.

In Switzerland the custom of clearing forest for the temporary cultivation of field crops, which dates back for a long time, was put to systematic use after 1840, at the time of the great potato disease. The method employed was to grow potatoes, or potatoes alternating with cereals, for 2 or 3 years, or sometimes up to 10 years, and then to plant spruce. This method of forming plantations was subsequently abandoned when it was found that the spruce, which generally developed well at first, subsequently became unhealthy and was attacked by red rot.

In the tropics the practice of clearing forest for temporary cultiva-

FIG. 5. Clear-cutting system with replanting of spruce, Postelwitz State Forest, Saxony. Part of a cutting section with narrow vertical coupes in hilly country. Felling direction from left to right (NE. to SW.), with 5-year intervals between fellings in adjacent coupes. Ages of coupes from left to right: (1) 15 years (trees in immediate foreground), (2) 10 years, (3) 5 years, (4) old wood about to be felled.

FIG. 6. Natural regeneration of Douglas fir, *Thuja plicata*, *Abies grandis*, and *Tsuga heterophylla*, sprung from seed stored in the ground, on an area devastated by fire; Vancouver Island.

tion is common among many primitive tribes, and under ordinary conditions it results in the destruction of extensive tracts of forest. If controlled and utilized for the formation of plantations of valuable trees, this otherwise harmful practice can be turned to very good account. The so-called *taungya* plantations of Burma, begun in 1869 and now covering a large area, have been created with the aid of temporary cultivation, usually of hill rice, on forest clearings in which all unmarketable timber is felled and burnt, the soil being enriched by the ashes. The plantations are chiefly of teak (*Tectona grandis*), which is introduced along with the field crop. These plantations have been formed efficiently and cheaply, while the cultivators provide local forest labour and grow their own food supply, a matter of great importance in tracts where communications are not good.

This method of regenerating clear-felled areas has since been applied not only in other parts of India but also in other countries where this primitive form of agriculture is practised. In East Africa it has proved to be a useful method of regenerating forests of pencil cedar (*Juniperus procera*) and other valuable trees.

4. CLEAR-CUTTING WITH NATURAL REGENERATION

Under certain conditions clear-cutting may be followed by successful natural regeneration. This may be obtained either (1) from seed already on the area, or (2) from seed disseminated from trees outside and usually adjoining it.

Regeneration from Seed already on the Area. In this case the seed either falls from the trees at the time of or shortly after felling, or is already lying on the ground or stored in it; sometimes the seed may be provided from both sources.

Examples. The best-known case of natural regeneration following clear-cutting is to be seen in the maritime pine (*Pinus Pinaster*) forests of the coastal regions of the Landes in south-western France. Clear-cutting is here carried out over large coupes, and natural regeneration springs up in abundance from seed, some of which is already on the ground, but much of which escapes from the cones of the felled trees in the months of April or May (see Figs. 7 and 8). Natural regeneration is specially favoured by the abundant annual seeding of the pine, the loose sandy soil, and the complete exposure to light of a species which demands it. After the felling and removal of the timber, the brushwood is spread evenly over the coupe in order to distribute the seed; this tends to produce an even stocking of the area with young plants.

The system of clear-cutting with natural regeneration is applied to the pedunculate oak in the valley of the Adour in SW. France. Here, owing to the mildness of the climate, the oak seeds abundantly every year. The areas are low-lying and subject to inundations, and there is a heavy undergrowth. After a coupe is cleared, the undergrowth is cut down, and any pre-existing oak seedlings are cut flush with the ground; these shoot up again, and large numbers of new seedlings appear from the seed lying on the ground, with the result that complete restocking is generally assured without artificial aid.

The lodgepole pine (*Pinus contorta*, var. *Murrayana*) and jack pine (*P. Banksiana*) of North America afford good examples of natural regeneration following on the destruction of the old crop by fire. The cones are borne in large numbers on the branches, and may remain there unopened for some years; the heat of a fire which may be sufficient to kill the trees will cause the cones to open and shed the seed, abundant natural regeneration resulting.

Natural regeneration from seed stored some time in the ground is well exemplified in the case of the Douglas fir and its associates in the Pacific coastal region of North America. Areas which are clear-felled often regenerate with great profusion, particularly if the debris is consumed by fire immediately after the felling and before the seed stored in the ground has time to germinate. Similar abundant regeneration may also follow the destruction of the old forest by fire (see Fig. 6).

These examples from North America indicate the applicability of the clear-cutting system, followed by the burning of debris, to the types in question. This treatment, however, could not be systematized unless the protection of the new crop from fire is assured, since there is no further store of seed in the ground to effect regeneration should the young crop be destroyed by fire.

One of the most remarkable instances of natural regeneration on clear-cut areas from seed stored in the ground is to be seen in the case of the teak (*Tectona grandis*) in Burma and Southern India. The seed is enclosed in a hard-shelled nut, and retains its vitality for many years. Where seed-bearers are plentiful the nuts accumulate in the ground, but germination does not take place until they are alternately heated by the sun and moistened by rain, when dehiscence takes place. This condition is secured by clear-cutting, which is followed by the appearance of large numbers of seedlings springing from seed which may have lain dormant in the ground for many years. The survival of these seedlings can be secured only

FIG. 7. Clear-cutting system with natural regeneration in the maritime pine forests of the Landes. A recently felled coupe, with temporary sawmill.

FIG. 8. Clear-cutting system with natural regeneration in the maritime pine forests of the Landes. On right, naturally regenerated crop 6 years old; on left, mature crop being tapped for resin; fire-line in centre.

by repeated and costly weeding, for which reason it is generally found less expensive to ignore the natural regeneration and to plant up the area in regular lines, so that weeding may be facilitated.

Regeneration from Seed disseminated from Outside. This form of regeneration applies chiefly to species with light or winged seeds which are disseminated by wind, as in the case of many pines and other conifers as well as certain broad-leaved trees like birch and various invasive tropical species which habitually spring up in quantity on recent clearings. Less commonly, water or animal agencies may operate, as in the case of the irrigated plantations of the Punjab in India, where the mulberry (*Morus alba*) springs up extensively on cleared areas from seed spread by irrigation water and by starlings.

In Europe clear-cutting with natural regeneration from adjoining woods or belts has been systematized chiefly in the case of the Scots pine, although it has been applied to other conifers, including the Austrian pine (*Pinus Laricio*, var. *austriaca*). The coupes are in the form of strip-like clearings[1] made in one of two different ways, either (1) by progressive fellings, or (2) by fellings in alternate strips.

These methods of regeneration should not be employed unless seed-years occur regularly and at frequent intervals, otherwise there is a risk of the soil being left exposed for too long a period.

Progressive fellings. Under this method, which is a very old one, the fellings proceed successively in a definite direction in the manner already described for the clear-cutting system with artificial regeneration. If the wind direction at the time the seed ripens is at all constant, it is a great advantage to arrange the fellings so as to proceed against this direction; by such an arrangement the seed is blown on to the adjoining cleared strip, the breadth of which should be such that seed in abundance will reach every part of it. The actual breadth of the strip must be determined by local

[1] It is a question whether a strip-like clear-cutting should be classed as a form of the clear-cutting system or as a form of strip system. The distinction is not always easy to draw. It is proposed to adopt as the most logical distinction that which is now generally recognized in Europe, namely, to reckon as a (clear) strip felling one which is so narrow that the adjoining old wood exercises a powerful influence on the strip in regard to soil moisture and other physical factors which affect seed germination and the growth of the seedling; the breadth of such a strip would be about half the height of the adjoining wood, or not much more. A strip-like clear-cutting, on the other hand, is not so influenced except possibly along the immediate edge of the adjoining wood. It follows, therefore, that clear-strip fellings apply generally to species like spruce, which are sensitive to drought in early youth and may benefit by lateral protection from the sun, rather than to hardy species like Scots pine, the seedlings of which demand much light and may be adversely affected by close proximity to an adjoining wood.

observations, since even in the case of one and the same species the distance to which the seed is disseminated in sufficient quantity must depend largely on the velocity and direction of the wind under average conditions.

The interval between successive adjacent fellings will depend on the frequency of seed-years and the readiness with which regeneration appears and establishes itself. If one strip is cleared, the one adjoining it should not be cleared until the original one is fully regenerated, for which purpose a liberal margin of time should be allowed. Assuming, for instance, that under the prevailing seeding conditions a period of 3 or 4 years is found to be sufficient to ensure the establishment of natural regeneration over a cleared strip of

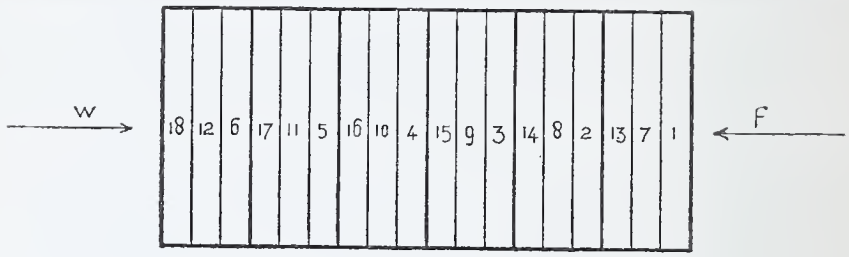

FIG. 9. Clear-cutting by progressive fellings with natural regeneration by seed from adjoining woods. Diagrammatic representation of an area divided into 6 cutting sections with 3 coupes in each ; interval between successive adjacent fellings 6 years. Numbers denote year of felling ; *f*, felling direction ; *w*, wind direction.

a certain width, then it should be safe to allow a period of, say, 6 years between the cutting of one strip and the cutting of the next one adjoining it. The arrangement of cuttings in such a case is shown in Fig. 9. In this example the area to be regenerated is divided into 6 cutting sections with 3 coupes of the required breadth in each, so that it will take a period of 18 years to fell and regenerate the whole. In the last coupe of each cutting section a belt of seed-bearers should be left along the windward side in order to regenerate the coupe, after which the belt should be felled and the blank strip regenerated artificially. In the diagram one self-contained area is shown; the 6 cutting sections might equally well be distributed over two or more areas if necessary.

More elasticity can be introduced into the working by allotting a number of areas for regeneration during a given period, and not rigidly fixing the interval between successive fellings ; this allows for the distribution of fellings over several areas, which will tend to equalize the area felled each year without too close an adherence to

a fixed scheme, to which the vagaries of natural regeneration may not always lend themselves.

Fig. 10 illustrates clear-cutting with natural regeneration from an adjoining wood in the case of the Austrian pine.

Fellings in alternate strips (Ger. *Kulissenhieb*). A method which has been tried from time to time is that of felling parallel clear strips, usually about 40–60 yards wide, through the wood to be regenerated, leaving intervening strips of similar width untouched; the cleared strips regenerate naturally, and the young crop is allowed to grow to an age when it is capable of producing seed in quantity, when the intervening old strips are clear-felled, and the process is repeated. This method has not proved satisfactory; apart from the difficulty of controlling it owing to the presence of two widely different age-classes distributed over the area, there is considerable waste of space, particularly in the case of pines, owing to the failure of regeneration along the edge of the strips left uncut.

A more workable and successful adaptation of this method is that begun experimentally about the year 1918 in the forest of Rouvray in Normandy, the species being Scots pine. Clear-cuttings were made in parallel strips 40 to 50 metres (averaging roughly 150 feet) wide, belts of untouched forest 15 to 20 metres (roughly 50 feet) wide being left between them to furnish seed (see Fig. 11). Natural regeneration established itself well on the cleared strips, the young plants growing vigorously in the enjoyment of full overhead light. When the young crop was sufficiently advanced, that is, about 6 years after the first felling, the intervening belts of seed-bearers were felled and the blank strips were sown up in patches. No account was taken of wind direction in cutting the strips, which were aligned in any direction more or less at right angles to roads, so that when the seed-bearers were felled the timber did not require to be dragged through the young crop.

The chief advantages of this system over the uniform system, which is employed in the forest in question and in which seed-bearers are left scattered singly over the area, are (1) greater security against wind, experience in this locality having shown that scattered trees are more subject to windfall than trees left in belts (see p. 53), and (2) avoidance of damage to the young crops during the felling and extraction of the seed-bearers. Its chief advantage over progressive fellings is that seed is scattered in two directions instead of one, a fact which would be of importance where the constancy of the wind direction could not be relied on.

Its chief defect is the necessity for regenerating artificially at

least one-third of the area, that is, not only the space actually occupied by the belts of seed-bearers but also a narrow strip on either side of them where regeneration fails, on which account this method of regeneration was abandoned after a few years' trial.[1] It owed its origin to the fact that strip-like clearings for artillery camps in the outskirts of the forests during the war were found to result in promising natural regeneration where this was not actually impeded by the camps; further strips were therefore cleared experimentally and kept under observation, with the results already noted.

5. ADVANTAGES AND DISADVANTAGES OF THE CLEAR-CUTTING SYSTEM

ADVANTAGES. The chief advantages of the clear-cutting system are as follows:

1. It is the simplest of all high forest systems, since it dispenses with marking operations requiring skill, occupying the time of the staff, and therefore costing money.

2. It represents the utmost concentration of work, every tree on the coupe being felled; this means a larger outturn per unit of area, and therefore greater economy in felling and extraction, than in systems where only a portion of the trees are felled at a time.

3. It affords complete overhead light, an important consideration in the case of strong light-demanders.

4. There is no damage done to the young crop through the felling and extraction of timber, since this is all completed before the young crop originates.

5. Owing to the even-aged condition of the stands it produces cleaner and more cylindrical timber than that produced by the more uneven-aged systems.

6. As a rule the new crop is established more rapidly under the clear-cutting system than under systems in which regeneration is established by degrees; this saving of time may be of considerable financial advantage.

DISADVANTAGES. The chief disadvantages of the system are as follows:

1. The complete clearance of the forest cover may produce conditions adverse to the growth of young plants of many tree species; such conditions are the following:

(*a*) Desiccation and general deterioration of the soil through exposure to sun and air currents;

[1] An attempt has been made recently to obtain natural regeneration along the strips occupied by the belts of seed-bearers by opening out the latter in the form of a seeding felling (see p. 32); the results of this experiment are awaited.

FIG. 10. Clear-cutting with natural regeneration from adjoining woods. Forest of Austrian pine (*Pinus Laricio*, var. *austriaca*); Steinfeld plains, Austria.

FIG. 11. Clear-cutting of Scots pine in alternate strips, with natural regeneration. Forest of Rouvray, France.

(*b*) Increase of swampiness in areas which tend to be swampy;
(*c*) A rank growth of grass and weeds, which may interfere with regeneration and add to the cost of establishing it;
(*d*) Exposure to frost and cold winds;
(*e*) Multiplication of injurious insects, particularly weevils, which tend to breed in clearings where stumps are present in abundance, and cockchafers, which are more prevalent in clearings than under a shelter-wood.

2. On hill-sides it exposes the area to erosion and, where the ground is unstable, to landslips, while it affords no safeguard against the rapid run-off of rain-water.

3. It results in the accumulation on the ground of large quantities of debris (slash) after the fellings; where utilization is not intensive, and tops and branches of some size are left lying on the ground, this debris forms the breeding ground of bark beetles, which are destructive more particularly to coniferous forests; this risk can be avoided by collecting and burning the debris.

4. It possesses the disadvantage of even-aged systems in general in producing a type of forest less resistant to damage by snow and wind than the more uneven-aged systems.

5. From the aesthetic point of view the clear-cutting system is the least desirable of high forest systems.

The disadvantages just mentioned are intensified if the coupes are large, or if the ground remains exposed for some time before the young crop closes up; they are reduced to a minimum where small or narrow coupes are adopted, or where the area is rapidly reclothed.

In connexion with insect damage, it may be noted that in the Scots pine forest of Isenburg in Hesse-Darmstadt clear-cutting followed by artificial regeneration with the aid of field crops was abandoned in 1885 in favour of natural regeneration under a shelter-wood, since the former system was found to encourage the multiplication of cockchafers, the working of the soil for temporary cultivation probably being a contributing factor.

6. EXPERIENCE OF THE CLEAR-CUTTING SYSTEM IN SAXONY AND SWITZERLAND

No account of the clear-cutting system would be complete without some reference to the abuse of silvicultural principles which has accompanied it in certain parts of Europe; this has led, in certain cases, to adverse results which have been cited, on occasion, in support of a condemnation of the clear-cutting system in general. The cases of Saxony and Switzerland may be specially considered,

although similar results might be quoted in the case of other parts of Europe.

Saxony. For more than a century Saxony has been one of the chief strongholds of the clear-cutting system in Europe. It was introduced by Cotta[1] at the beginning of the nineteenth century as the only means of regenerating forests which had suffered to such an extent from unregulated selection fellings and excessive grazing and removal of litter, that natural regeneration was out of the question. The forests of Saxony may be considered as occupying three different zones of altitude: (1) the upper zone, about 600 metres (1,950 feet) and over, where spruce thrives under the influence of an ample rainfall; (2) the middle zone, 800–1,950 feet; (3) the lower zone, below 800 feet, with a rainfall of only 20 to 25 inches, which is too low for the healthy growth of spruce. In the mountainous parts of the country the original forest probably consisted of spruce mixed with silver fir, Scots pine, and beech. In the lower zone spruce is everywhere an introduced species.

One important result of the clear-cutting system was that the tender beech and silver fir largely disappeared, their place being taken by spruce, a species better adapted for this form of treatment. In this way large areas of mixed forest were converted into pure spruce, a condition which was viewed with alarm by Cotta himself, as is shown by his warnings, as early as 1820, against the indiscriminate planting of this species. Later on, under Pressler's influence, the policy of planting pure spruce was still more vigorously prosecuted for financial reasons, since it was found that spruce, worked on a comparatively short rotation for paper-pulp and mining timber, gave the best financial results.

The adverse effects of this policy began to be noticed as far back as 1869, when a reduction of growth was observed in young spruce woods, as compared with that of the previous rotation. About this time Gayer in particular issued warnings against a continuance of the policy of planting pure spruce under the clear-cutting system, and advocated a return to mixed crops and shelter-wood systems; but in Saxony, at all events, these warnings passed unheeded. By 1920 the increment had fallen to such an extent that in certain cases woods had to be placed two quality classes (out of five) below the assessment of 30 years previously. During recent years the unhealthy state of many of the coniferous woods in which spruce predominates has become more and more evident. The outward

[1] Heinrich von Cotta, 1763–1844, Director of the Forest Academy of Tharandt, Saxony, 1816–44; one of the foremost authorities of his day.

signs are stunted growth, short yellow needles, a growth of lichens on the trees, and the appearance of *Chermes* in quantity on the shoots. The ground vegetation has also changed, heather replacing grass, *Epilobium*, blackberry, raspberry, and other plants indicative of active nitrification; a peaty formation with a covering of lichens is frequently present, and in some cases a hard pan has formed some little distance below the surface.

In 1921 Dr. E. Wiedemann undertook a series of investigations with the object of determining the causes of these unsatisfactory conditions, and after two years of steady work he published his results in 1923 and 1924.[1] In the course of these investigations he examined and analysed a large number of soil samples, made numerous stem analyses, and also utilized the excellent records of operations in the forests of Saxony dating from 1817. He found that the production of crops raised on clear-cut areas had diminished considerably as compared with that of crops raised under shelter-woods, the worst results occurring where the mixture of beech had disappeared. The mean annual loss of increment during the past 100 years was estimated at 0·65 cubic metres per hectare, or 9·29 cubic feet per acre, representing an annual loss of over $3\frac{1}{2}$ million cubic feet over the whole of the Saxon State forests. Further, judging by the decrease of increment in woods already twice clear-cut, there were indications that this decrease would be intensified if clear-cutting and planting were persisted in.

Dr. Wiedemann's investigations brought out the important fact, revealed from a study of height curves, that a definite period of stagnation of growth occurred more or less in the same year in different widely separated localities; this was most noticeable in the case of pure spruce, without beech. Similar stagnation of growth was observable in woods raised under a shelter-wood, but it was less well-marked and of shorter duration. It was worst in the lowest, prevalent in the middle, and only slight in the highest zone. Where it was not excessive, and where the spruce formed a canopy, the woods were found after a time to grow on fairly satisfactorily unless a second period of stagnation intervened. These periods of stagnation of growth were found to be correlated with diminished rainfall during the growing season, and occurred after drought years which reduced the amount of moisture below the minimum required for healthy growth. The evil effects of the drought were intensified by

[1] (*a*) *Zuwachsrückgang und Wuchsstockung der Fichte* (W. Laux, Tharandt, 1923).
(*b*) 'Fichtenwachstum und Humuszustand' (*Arbeiten aus der Biologischen Reichsanstalt für Land- und Forstwirtschaft*, XIII. 1, 1924).

the disappearance of the beech. A concomitant factor was the unfavourable decomposition of humus as a result of long exposure which inhibited the production of nitrates, except in soils of greater fertility than those commonly devoted to forests, or under the influence of favourable climatic conditions. Former mixed woods regenerated under a shelter-wood were found to be free from these adverse conditions.

Dr. Wiedemann's investigations have indicated the steps to be taken to remedy matters, namely, (1) a return to shelter-wood methods and a mixture of beech and silver fir with the spruce, and (2) the raising of the rotation with the view of obtaining natural regeneration. These measures have already been initiated, and this will mean a departure from purely financial considerations where these are antagonistic to good silviculture.

Switzerland. The experience of Switzerland is somewhat similar to that of Saxony. During the eighteenth century the forests of that country were much depleted by wasteful methods of working, and by the beginning of last century drastic action was necessary in order to remedy matters. In the early part of the century, great progress was made in Germany with clear-cutting followed by artificial regeneration by planting, a system which promised good results. From about 1820 onwards for a time almost all the Swiss foresters had had their training in Germany, and were influenced by the new German system, which was consequently introduced into Switzerland.

The original forests of Switzerland consisted largely of a mixture of spruce, silver fir, and beech, but since the two last-named species are very sensitive to frost during youth, the introduction of the clear-cutting system led to their extinction over considerable areas, and a great extension of pure spruce woods resulted. The spruce succeeded well for 30 or 40 years, and proved economically valuable, and hence its cultivation was rapidly extended to regions below its natural habitat, where it replaced the indigenous hardwoods and silver fir. Natural regeneration was abandoned by degrees, and continued only in the forests of the mountains; even in the latter clear-cutting with artificial regeneration was largely extended during the second half of the nineteenth century.

The effects of this policy in time became evident through decreased increment, accompanied by heart-rot, in the pure spruce stands, particularly in localities below the natural region of this species, and through damage by storms and snow in the even-aged spruce woods of the mountains. Hence when Gayer declaimed against the wholesale growing of pure spruce woods, and advocated

the adoption of more natural methods, he found willing listeners in Switzerland. The clear-cutting system with artificial regeneration of pure spruce, therefore, has fallen into disrepute in that country, where it is being replaced by more natural methods, and the law now prohibits large clear-cut coupes in the mountains.

Conclusions. The evidence afforded by the investigations in Saxony appears to warrant the following conclusions and comments:

1. The adverse results described are due in part only to the adoption of the clear-cutting system; this is evident from the fact that they are also observable to some extent in woods raised under a shelter-wood.

2. These adverse results are intensified by, and are probably due in no small measure to (*a*) the substitution of pure spruce for the original mixed crops, (*b*) the introduction of spruce into regions outside its natural habitat, where the rainfall is insufficient to promote its healthy growth.

3. No evidence has been produced to show the effect of growing mixed crops of spruce, silver fir, and beech both inside and outside the natural habitat of these species in Saxony, in order to compare the results with those obtained by growing pure spruce in the same localities. Without such evidence it is impossible to say to what extent the adverse results are due respectively to (*a*) the adoption of the clear-cutting system, (*b*) the cultivation of pure spruce, (*c*) the wrong choice of locality.

Although the causes of the adverse results do not appear to have been investigated in so much detail in Switzerland as in Saxony, the evidence available from the former country also leaves us somewhat uncertain as to the extent to which the clear-cutting system as such, rather than the cultivation of pure spruce, often outside its natural habitat, is responsible for the bad results. Nevertheless the object lessons afforded by Saxony, Switzerland, and other countries where the clear-cutting system has been wrongly applied, have led at times to the unjustifiable condemnation of this system in general. It is true that in localities subject to severe frosts a mixture of beech and silver fir would be difficult, if not impossible, to secure under the clear-cutting system, and hence if such a mixture is desired this system is not suitable. But the financial policy of Saxony deliberately aimed at pure spruce, and while this policy was followed no serious efforts were made to secure a sufficient mixture of the other species. Switzerland also appears to have been carried away for a time by the glamour of the financial returns yielded by pure spruce crops.

We are hardly justified, therefore, in condemning the clear-cutting system out of hand on the evidence afforded by its application to pure spruce woods. The system has its drawbacks, and may be inapplicable under certain conditions, but on the other hand it is in many cases the only possible system to adopt with success. Its application under different conditions will therefore be considered in the next section.

7. APPLICATION OF THE CLEAR-CUTTING SYSTEM

Conditions of Application. The examples of Saxony and Switzerland show that while the clear-cutting system is simple in execution, it is on this very account a powerful instrument in the hands of man owing to the fact that it lends itself readily to artificial measures. It is therefore the more necessary to guard against its abuse. Before considering the conditions under which the clear-cutting system should be applied, it is necessary to emphasize the fact that although typically an even-aged system, it does not necessarily involve the growing of pure crops, as is sometimes alleged against it. It is true that in some of the best-known examples of clear-cutting with natural regeneration (cf. pp. 11–13) pure crops are produced, but in the case of the Scots, Austrian, and maritime pines, to quote three instances only, a shelter-wood system in the same localities would also produce pure crops. Where artificial regeneration is practised, any mixture of species can be adopted that the locality will permit and the circumstances of the case may demand: the chief difficulties to be faced in this connexion are the correct choice of species and the best method of forming the mixture.

Before deciding on the adoption of the clear-cutting system in any locality it is necessary to consider various points in relation to each other and to the local conditions; among the more important of these are the following:

1. Species. The clear-cutting system is specially indicated for strong light-demanders which will not tolerate a shelter-wood; but in areas subject to frost, drought, or other risks it is unsuitable for sensitive shade-bearers which will not stand exposure in youth, although these may be introduced on clear-cut areas with the aid of nurses. Wessely, however, writing in 1853, stated that in the Austrian mountains some of the finest young beech woods had been produced on clear-cut areas.

2. Locality. The clear-cutting system is unsuitable, at all events with large coupes, (*a*) for unstable hill-sides or where serious erosion, snowslides or avalanches are to be feared, (*b*) in catchment areas

where the water-supply is likely to be endangered, (*c*) for 'protection forests', i.e. forests maintained primarily for protective purposes.

3. Soil and soil-covering. The clear-cutting system is unsuitable where the soil is liable to serious deterioration through temporary exposure, or where clear-cutting is followed by a heavy growth of weeds which prevent regeneration except at prohibitive cost; the latter difficulty may be counteracted by the temporary cultivation of field-crops, and by artificial regeneration with regularly spaced plants, which facilitates weeding. It is sometimes maintained that the clear-cutting system is suitable only for fertile soils, and should be avoided on poor soils; this is not borne out in practice, since some of the most light-demanding species, such as birch and certain pines, which do not tolerate cover during youth, frequently occur on poor soils and can best be regenerated under the clear-cutting system. Where natural regeneration is relied on, fertile soils may be a positive disadvantage owing to the competition of weeds.

4. Conditions for regeneration. The clear-cutting system should not be introduced unless regeneration each year or period of years can be absolutely assured. With natural regeneration this involves conditions favourable to the rapid seeding of the coupe and the successful establishment of the young crop. With artificial regeneration it involves a sufficiency not only of seed or plants but also of suitable labour during the season of sowing or planting; in the tropics planting is usually done in the rainy season, when forest labour is sometimes difficult to obtain.

5. Type of forest produced. The clear-cutting system, in common with other systems producing more or less even-aged crops, is well adapted for the production of large quantities of material of special dimensions, for instance mine-props or pulpwood. Even-aged crops, however, are more susceptible to damage by wind and snow than uneven-aged crops, though the risk can be lessened by attention to thinnings, by an admixture of species resistant to wind or snow, and by a suitable arrangement of coupes and cutting sections. In many mountainous regions of Europe uneven-aged crops are deliberately aimed at owing to the risk of damage by snow and storms.

6. Change of species or composition of forest. The clear-cutting system is the one most commonly adopted for replacing an existing forest by one consisting largely or entirely of new species; in the case of the more sensitive shade-bearers, however, new species are often introduced under the protection of the old wood. Where an existing wood has become derelict through mismanagement or

neglect, the clear-cutting system with artificial regeneration is usually the only one by which it can be brought into a satisfactory state.

A type of forest more commonly represented in the tropics than elsewhere is that in which many different species of trees are mixed together, only one or a few of which are marketable. The clear-cutting system may be adopted to replace such forest by plantations of valuable species. The circumstances of each case must determine (*a*) whether the clear-cutting system is permissible on silvicultural grounds, (*b*) whether the felling of undersized trees of valuable species, at present unmarketable but with a high potential value, is justified, (*c*) whether the felling of large numbers of trees of different species, at present unmarketable, is justified in view of the possibility of a future demand, (*d*) whether the cost of felling and burning a large number of unmarketable trees is justified by the results likely to be obtained by replacing the old crop by a more valuable new one. So far as the last point is concerned, the cost can be reduced considerably by utilizing the practice of shifting cultivation, by which coupes are cleared without cost by cultivators who raise field crops on the area for one or more years and form plantations of trees on the clearings.

7. Economic considerations. The economic advantage of felling and extracting the largest quantity of timber from the smallest area in the shortest time is so great, that the clear-cutting system has been frequently adopted on the ground that under no other system could remunerative exploitation have been undertaken. This applies particularly to places in which ordinary means of transport are deficient, and in which the construction of special export works, such as tramways, ropeways, and the like is necessary. For this reason the clear-cutting system has sometimes been practised in regions where physical conditions have been against its adoption, as in the Austrian mountains, where it has been in operation for many years, with large coupes and artificial regeneration, on terrain naturally unsuitable for it. It must be admitted, however, that there have been some serious failures in restocking, resulting in loss of time and money. In these mountains it is only within recent years that steps have been taken, partly as a result of improved communications, to replace these large clear-cuttings by shelter-wood systems or clear-cutting in narrow strips.

Application in Practice. The progressive clear-cutting system with natural regeneration from adjoining woods appears to have been in operation in Germany for some hundreds of years, the

coupes being long and narrow for seeding purposes. In Europe the clear-cutting system with artificial regeneration began to receive serious attention about the middle of the eighteenth century; its effectiveness and the sureness of its results brought it more and more into favour, so that by the end of the century it was in full swing. In France considerable areas of poor gravelly sand, originally supporting a scrubby growth of oak and other hardwoods, were clear-felled and regenerated artificially with Scots or maritime pine; in inland regions the former is now preferred to the latter, and has replaced it on all but the poorest soils.

It was in Germany, however, and in countries influenced by German ideas, that clear-cutting came to be most widely practised, although it was not until 1811 that Cotta systematized it by the formation of cutting sections with the object of affording protection against the wind. In the Austrian Forest Ordinance of 1786 the clear-cutting system with artificial regeneration is recognized as the general system in force. In Germany oak was among the first species employed for reafforesting clear-felled areas, and there are many fine examples of oak woods raised by dibbling acorns, often in conjunction with the raising of field crops. During the latter half of the eighteenth century and subsequently, much reafforestation of poor sandy areas was carried out by means of sowings of Scots pine. Spruce, however, is the species with which the clear-cutting system has been most widely associated. As we have seen, its economic value and its adaptability to this system, owing to its comparative hardiness, led to its extensive cultivation, often in localities outside its natural habitat; hence one of the most important effects of the clear-cutting system in Central European countries has been the supersession of the original forest types by crops of pure or nearly pure spruce. Thus economic considerations prevailed against good silviculture, with the result that the adverse effects of growing pure spruce in unsuitable situations began to make themselves apparent, and a conflict arose in the early part of the nineteenth century as to the suitability of the clear-cutting system as compared with shelter-wood systems (see p. 29). The Baden Forest Law of 1833 actually prohibited the clear-cutting system, and this prohibition is still on the statutes, although it is ignored in practice. The conflict in regard to the clear-cutting system has been renewed from time to time with great bitterness, and has been revived in recent years owing largely to the experience of Saxony, with the result that opinion generally has veered round in favour of more natural methods of treating and regenerating

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woods. This applies not only to Germany but also to Austria, Czechoslovakia, and other countries where the clear-cutting system has been widely practised in the past. Although this system is being superseded by systems involving more natural methods of regeneration, it is still practised in Europe to a considerable extent, and in certain cases the great economic advantage of concentrated fellings has led to its retention for a time even where its application on other grounds might seem undesirable, as in the case of the Austrian mountain forests.

In Great Britain clear-cutting with artificial regeneration is much more widely practised than any other form of treatment in high forest, but frequently there is little or no attempt at systematic method. This system is likely to play a leading part in British forestry for many years to come, owing mainly to the following causes:

1. The existence of woodlands rendered derelict by past mismanagement, which could not be regenerated satisfactorily in any other manner.

2. The prevailing policy of introducing exotic conifers to replace the existing types of forest, for economic reasons.

3. The necessity for fencing against rabbits, requiring the utmost concentration of regenerative work in order to justify the cost of fencing.

The large schemes of afforestation begun after the war and now in progress necessitate the creation of artificial woods on a large scale on bare land or on cleared derelict woodland areas; nevertheless it is not improbable that when these woods come to maturity, systems other than the clear-cutting system will in many cases be found applicable to them.

The lumbering operations of Canada and the United States, by which extensive areas of forest have been cleared, are examples of clear-cutting on a large scale; this method of working was adopted primarily on economic grounds, in order to reduce the cost of working to a minimum by felling and removing the largest possible quantity of timber from a given area in the shortest possible time, often by specialized methods of extraction. For the most part these operations have been purely destructive and have no claim to be classed as the clear-cutting system, since no attempt has been made at regeneration.

In certain parts of the tropics the clear-cutting system has played an important part, and it is likely to play a still greater rôle in future. Most tropical forests consist of a large number of different species,

of which only a few are marketable, and in order to increase the proportion of valuable species artificial methods frequently have to be adopted. The method which has been found most economical and successful is that of forming plantations of the desired species on areas cleared of forest for temporary cultivation with field crops. The future of tropical forestry is likely to be influenced in no small measure by the extension of this form of the clear-cutting system.

The increasing attention given to the formation of plantations of exotic species in South Africa, Australia, New Zealand, and other countries outside the tropics, indicates that in these regions also the clear-cutting system is likely to play a very important part in the future. And in general, the predicted world shortage of timber, particularly of soft woods, is a factor which is likely to raise the importance of this system to a level never attained before, since measures necessary to meet this shortage must include the formation of extensive plantations of conifers on areas where they have not existed previously or where they have been depleted by wasteful methods of working. Everything therefore points to the increasing importance of the clear-cutting system in spite of any disadvantages it may possess.

III

SYSTEMS OF SUCCESSIVE REGENERATION FELLINGS AND SHELTER-WOOD SYSTEMS

1. SYSTEMS OF SUCCESSIVE REGENERATION FELLINGS

Under the clear-cutting system, as we have seen, the area to be regenerated is cleared by a single felling, and where natural regeneration is relied on from seed shed by the trees on the area itself, complete restocking is secured in one season as a result of this single felling. This is possible only (1) where conditions of seeding and regeneration are unusually favourable, and (2) where it is not necessary to retain any portion of the old wood for the protection of the young crop against frost, drought, or other dangers.

In the great majority of cases, however, complete natural regeneration will not follow from a single felling, while in the case of sensitive shade-bearers protective cover for the seedlings may be necessary for some years after they appear. In either case part of the old wood has to be retained for a time for the provision of seed or for protective purposes. Thus the old wood is removed not by a single felling but by two or more successive fellings, and the new crop establishes itself from seed shed by trees retained on the area; these trees are termed *seed-bearers*. In certain cases the new crop may be introduced artificially under the protection of the old one, the latter being subsequently removed in one or more fellings. The term *systems of successive regeneration fellings* is accordingly used to denote collectively those systems under which definite areas are regenerated by two or more successive fellings (known as *regeneration fellings*) extending over a period of years. The nearest French equivalent is perhaps *Futaie régulière*, but since this denotes even-aged high forest in general it would include the clear-cutting system. *Méthode de régénération par coupes successives* (or *progressives*) is a term used to denote the uniform system; employed in the plural this term would express most clearly the idea of shelter-wood systems in general. The nearest German equivalents are *Schlagweiser Hochwald* or *Schlagbetriebe*, but these terms would, strictly speaking, include also the clear-cutting system.

The distinction between the different systems of successive regeneration fellings lies not in the general framework, which is not peculiar to any one system and is itself subject to various modifica-

tions, but rather in the method of carrying out the regeneration fellings and distributing them in space and time. The difficulty of devising a satisfactory classification of silvicultural systems applies with special emphasis to the systems of successive regeneration fellings, which show a large number of variations, often merge into each other, and are frequently used in combination. Continental terminology tends to confuse rather than to assist, since the same term is often used by different writers in a different sense, while undue importance is sometimes attached to trivial variations. Following the classification given on p. 2, the systems in question will be dealt with in the following order:

1. The uniform system.
2. The group system.
3. The irregular shelter-wood system.
4. Strip systems.
5. The wedge system.

In describing these systems it is proposed to deal with the uniform system in some detail, as its technique is based on principles many of which apply also to the other systems.

2. ADVANTAGES AND DISADVANTAGES OF SHELTER-WOOD SYSTEMS

Shelter-wood systems are those high forest systems in which the young crop is established under the shelter (overhead or lateral) of the old one; the latter at the same time affords protection to the soil. Shelter-wood systems include the various systems of successive regeneration fellings together with the selection system. As we have seen (p. 25), the question 'shelter-wood *v.* clear-cutting' has been the subject of much controversy in the past, and it will be of interest to consider the main advantages and disadvantages of shelter-wood systems, more particularly in comparison with the clear-cutting system.

Advantages of shelter-wood systems: 1. In general, though not universally, they aim at natural regeneration whereas the clear-cutting system usually, though not invariably, has to rely on artificial regeneration. Such advantages as natural regeneration may possess, therefore, are more frequently obtained under the shelter-wood systems than under the clear-cutting system.

2. They afford protection to species sensitive in youth to frost, drought, and cold winds; such protection is not afforded under the clear-cutting system except with very small or narrow coupes.

3. The soil is more effectively protected than under the clear-cutting system, particularly where the canopy is opened gradually

and cautiously: there is less risk of desiccation and the invasion of noxious weeds.

4. There is less risk of the multiplication of those injurious insects which habitually breed in clearings.

5. On steep or unstable hill-sides there is less risk of erosion or the rapid run-off of rain-water than under the clear-cutting system.

6. By adopting certain forms of shelter-wood system more effective measures can be taken to guard against damage by storms and snow than under the clear-cutting system.

7. An opportunity is given to the best trees to put on enhanced increment when opened out in regeneration fellings.

8. From the aesthetic point of view shelter-wood systems are usually preferable to the clear-cutting system, particularly if the old crop is removed gradually.

Disadvantages of shelter-wood systems: 1. Shelter-wood systems require more skill and occupy the time of the staff to a greater extent than the clear-cutting system, owing to the necessity for marking trees either for felling or for retention.

2. Work is less concentrated than under the clear-cutting system, and hence felling and extraction cannot be carried out so economically.

3. Damage is done to a greater or less extent by felling trees over young growth and dragging or sliding timber through it; the amount of damage varies with different systems, and can be almost entirely prevented by suitable precautions.

4. In most cases the young crop takes more time to establish than under the clear-cutting system; this loss of time may mean serious economic loss.

5. The rate of cutting and regeneration are more difficult to control than under the clear-cutting system.

IV

THE UNIFORM SYSTEM

1. TERMINOLOGY

The term *uniform system*, which may be taken as an abbreviation of *shelter-wood uniform system*, implies a uniform opening of the canopy for regeneration purposes, as well as a uniform or even-aged condition of the young crop produced thereby. The system is also known as the *shelter-wood compartment system*, sometimes abbreviated to *compartment system*, denoting that the canopy is opened out for regeneration over whole compartments at a time. The terms *shelter-wood system* and *system of successive regeneration fellings* are sometimes applied to the uniform system in particular; it is preferable, however, to regard them as collective terms rather than as applicable to any one system.

In American literature the term *seed tree method* is sometimes used to denote a form of the uniform system in which the seed-bearers are widely spaced over the area.

The French term in general use is *méthode de régénération par coupes successives* (or *progressives*). The terms *futaie régulière* (even-aged high forest) and *futaie pleine* (fully stocked high forest) are often applied to the uniform system in particular. The term *méthode du réensemencement naturel et des éclaircies*, first used by Parade, is still sometimes employed (see p. 61).

Among German terms the following may be mentioned:

Schirmschlagbetrieb, dating from the middle of the eighteenth century.

Schlagweise Schirmbesamung, G. L. Hartig, end of the eighteenth century.

Schlagweise Schirmverjüngung.

Dunkelschlagbetrieb, or *Hartigscher Dunkelschlagbetrieb*, implies a slight initial opening of the canopy, as in the case of shade-bearers.

Femelschlagbetrieb, originally applied to Hartig's uniform system, but now applied more commonly to the group and irregular shelter-wood systems (Bavarian *Femelschlag* and Baden or Swiss *Femelschlag*).

Schirmgrossschlag, a term used by Wagner to denote shelter-wood (uniform) fellings extending over whole compartments as opposed to strips.

2. GENERAL DESCRIPTION

In describing the uniform system it will be convenient to begin with a young even-aged crop of such species as oak or beech and follow it through the different stages of its life until it reaches maturity and is removed to make room for a new crop. In its early stages, up to 25 years, such a crop is subjected to cleanings and early thinnings in which adventitious species such as birch, aspen, and willow, as well as branchy 'wolf' trees, are removed; otherwise the crop is kept in a dense condition in order to kill off side branches and encourage the production of clean stems. The characteristic density of these even-aged young crops may be seen from Fig. 20. Thereafter the crop is subjected to periodical thinnings to remove undesirable stems and promote the development of the better members of the crop. It is important that the thinnings should stimulate good crown development, in order to produce good seed crops later on; but it is equally important that the canopy should not be broken permanently, as this is likely to result in a rank growth of weeds and grass which may prevent natural regeneration when it is wanted.

We may now assume that the crop is approaching the age at which it is desired to fell and regenerate it. If the thinnings have been judiciously carried out, it should consist of trees with long straight sound clean boles and well-developed crowns forming a complete canopy and capable of producing good crops of seed; trees with good crowns will have correspondingly well developed root-systems, so that if the crop is opened out they should be reasonably wind-firm. Owing to the closed canopy there should be no rank weed-growth on the ground, the soil-covering, if there is any present, consisting at most of a sparse growth of shade-loving plants.

The time has now arrived for the *regeneration fellings*. These consist of two main categories: (1) the *seeding felling*, under which the canopy is opened out in order to afford sufficient light to ensure the survival for a short time of seedlings springing from seed shed by the overhead trees; and (2) *secondary fellings*, under which the mother trees are removed in one or more fellings at suitable intervals in order to admit more light to the seedlings which have appeared. The last of the secondary fellings is termed the *final felling*; this is carried out when the young crop is well established.

Fig. 12 shows diagrammatically the different stages in the progress of regeneration. A crop in which the seeding felling has been carried out is said to be in the *seeding stage* (Figs. 13, 14, 17, 18, 22); one in which secondary fellings have already begun is said

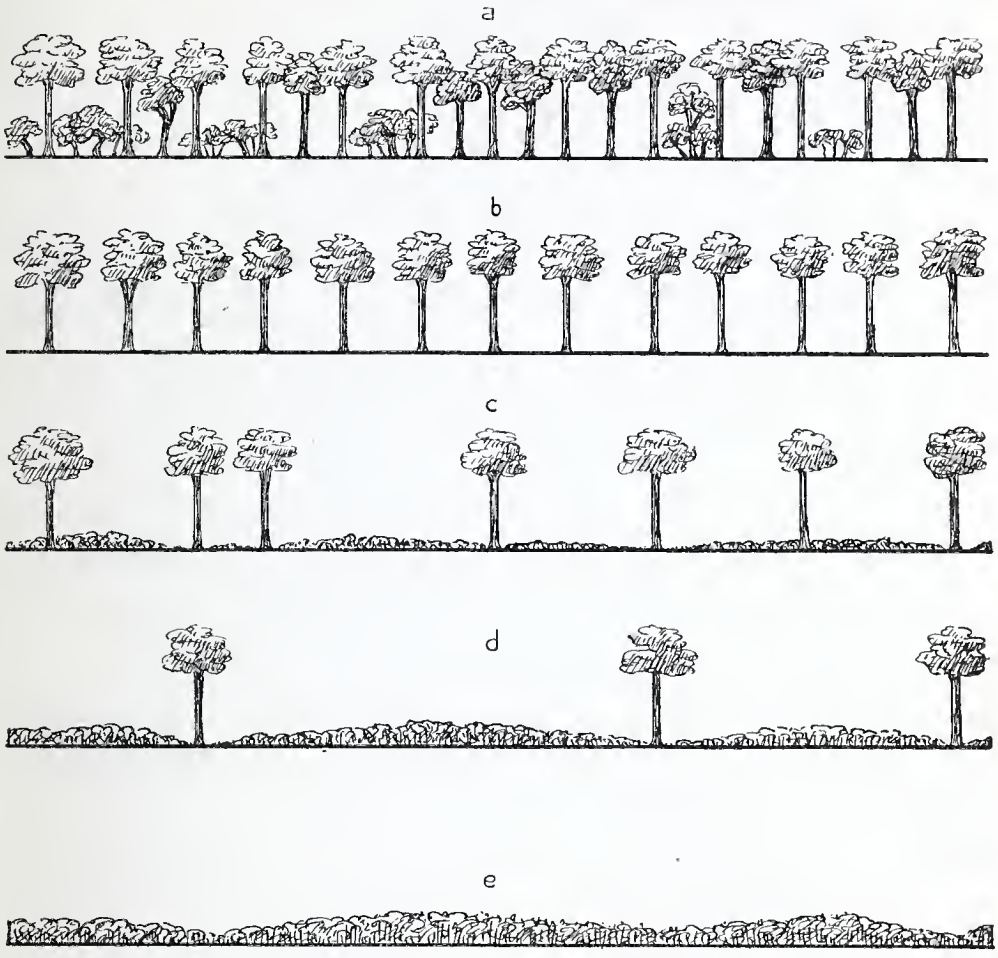

Fig. 12. Uniform system, showing successive stages of regeneration in beech forest. *a*, old crop with closed canopy, prior to seeding felling; *b*, seeding stage; *c*, secondary stage; *d*, final stage; *e*, young regenerated crop.

to be in the *secondary stage* (Figs. 16, 26); and one which only awaits the final felling is said to be in the *final stage* (Figs. 19, 23, 25).

At one time it was customary to carry out a *preparatory felling* (Fr. *Coupe préparatoire*, Ger. *Vorbereitungshieb* or *-schlag*, *Vorhieb*, *Vorgriffshieb*) shortly before the seeding felling, or in certain cases two or more preparatory fellings extending over a short period, say up to 10 years. The object of these fellings was to promote crown

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development and seed production, and to admit the sun's rays in order to hasten the decomposition of the humus layer and produce a good germinating bed by exposing the mineral soil. G. L. Hartig (who first used the term *Vorgriffshieb* in 1834) recommended preparatory fellings in places where seed-years are rare, so that on the occurrence of a seed-year a large area may be ready for seeding fellings. In modern European practice preparatory fellings have been generally discarded. It is now recognized that crown development cannot be secured satisfactorily by a single felling, or even by two or more fellings, carried out a short time before the seeding felling. The correct time to promote crown development is throughout the greater part of the life of the crop, that is, by means of judiciously executed thinnings repeated at fairly frequent intervals from the time the crop is in the young pole stage to the time when regeneration fellings begin. The decomposition of the humus is also promoted by this means, and a further stimulus in this respect is secured by making the last thinning before the seeding felling somewhat heavier than usual. But at the present day preparatory fellings are not generally recognized as a definite stage in the regeneration fellings, and in France *coupes préparatoires* are now commonly understood to mean provisional or preparatory fellings carried out during the process of conversion from one system to another.

It follows from what has been said above that the life of a wood treated under the uniform system—and this applies to shelter-wood systems in general—may be divided into two phases: (1) education or preparation, in which the wood is subjected to early cleanings followed by periodical thinnings extending over a considerable portion of its life and fitting it for the process of regeneration, and (2) regeneration, beginning with the seeding felling and ending when the final felling has been carried out and the young crop is fully established.

The present-day tendency is to pay more attention than was formerly the case to the 'education' of the crop with the object of bringing it into a condition which will favour regeneration when the time comes. This is effected by means of light but frequent thinnings throughout the education stage, these thinnings often increasing in intensity up to the time of regeneration, so that the transition from education to regeneration may be almost imperceptible, and the seeding felling is merely the breaking down of the last barrier that prevents the fecundity of Nature from having full play. Some Continental foresters of long experience maintain that

FIG. 13. Beech under the uniform system. Unopened mature crop on right of path; seeding felling just completed on left by removal of one-quarter of the crop. Lyons la Forêt, Normandy.

FIG. 14. Beech under the uniform system. Seeding stage, with natural regeneration beginning to establish itself in quantity. Spessart, Bavaria.

FIG. 15. Beech under the uniform system. Natural even-aged crop 60–70 years old, one of the oldest crops produced under this system in France. Lyons la Forêt.

in the case of shelter-wood systems generally, at least 50 per cent. of the total production of a wood during its life should be yielded by thinnings.

3. REGENERATION FELLINGS

Fr. *Coupes de régénération*; Ger. *Verjüngungshiebe.*

Regeneration fellings, as we have seen, may be grouped into two main categories, (1) seeding fellings, and (2) secondary fellings, ending with the final felling.

The Seeding Felling. (Fr. *Coupe d'ensemencement*; Ger. *Besamungshieb*, *Samenschlag*, *Angriffshieb*, *Dunkelschlag*; the last-mentioned implies a slight opening of the canopy, primarily for the regeneration of shade-bearers.) If thinnings have been properly executed throughout the life of the crop, by the time regeneration is desired the trees should be in a condition to bear plentiful crops of seed and the soil should be in a receptive condition, free from any excessive growth of weeds or any thick layer of undecomposed humus. The canopy should be closed, since a close canopy means an absence of heavy weed-growth. The trees themselves should, by a long process of selection during the thinning stages, be the best seed-bearers available, the different species being as far as possible in the desired proportion and the trees themselves being the best of their kind, with well-developed but not too spreading crowns and long clean boles. They should have reached the minimum but should not have exceeded the maximum age at which seed is produced in abundance.

The object of the seeding felling is not to stimulate seed-production, but to admit sufficient warmth from the sun to promote germination, and sufficient light to enable young seedlings to survive for two or three years, or until it is necessary to admit more light by a further opening of the canopy. With the majority of species success is best assured by carrying out seeding fellings only in good seed-years, and this rule is very commonly observed. This is particularly necessary (1) where good seed-years occur at long or irregular intervals, (2) where the seed is perishable, (3) where the opening of the canopy is likely to result in a heavy growth of weeds —and particularly in a matted covering of grass—or in the deterioration of the soil. In such cases it is generally advisable to await the ripening or even the fall of the seed before carrying out the felling; this affords a greater supply of seeds and avoids any risk of mistakes in the event of the premature destruction of the seed-crop by storms or other calamities. On the other hand good seed-years need not necessarily be awaited (1) where they occur at frequent and regular

intervals, (2) where seed stored in the ground retains its vitality for some years, and (3) where the opening of the canopy is not likely to result in heavy weed-growth or soil-deterioration before the young crop can establish itself. Under the favourable conditions prevailing in western France, for instance, seeding fellings are often carried out in oak, beech, and Scots pine forests without regard to the occurrence of seed-years.

In carrying out a seeding felling it should be remembered that the ideal of the uniform system is to obtain even-aged masses of regeneration over whole compartments or other areas of some size. In selecting seed-bearers, great importance is attached to loftiness of bole and an even distribution of crown cover. High well-distributed cover admits light to the ground evenly and not in large patches of direct sunlight, and this is an important factor in securing an even crop of regeneration. Hence trees with long clean boles and well-developed crowns should be selected as seed-bearers, trees with narrow or straggling crowns with a tendency to low branching, together with diseased and defective stems, being felled wherever possible. If any low-branching trees have to be retained as seed-bearers or for cover, it is permissible to prune off the lower branches. Small trees and even shrubs forming an underwood should be removed, since these prevent light, warmth, and rain from reaching the ground, and adversely affect regeneration.

Where the uniform system is practised in its ideal form under favourable conditions, advance growth is generally removed at the time of the seeding felling. Solitary saplings or groups of saplings, even if they recover from the suppression which they have endured so far, develop into branchy 'wolf' trees and interfere with the regularity of the young crop. An exception to this rule is where large gaps have been created by wind or other agencies and have become filled with masses of promising regeneration of sufficient extent to form self-contained crops. Again, in the case of mixtures of shade-bearing and light-demanding species, promising advance growth of the former may be left while the regeneration of the latter is secured by the seeding felling. Where conditions are less favourable, and advantage has to be taken of the presence of any advance-growth that may appear, we reach the border-line between the uniform system and the group system.

The extent to which the canopy is opened depends on species and on climatic and other factors. In the case of sensitive shade-bearers requiring protection from frost, drought, or cold winds, and species with heavy seeds, the opening should be slight to moderate, whereas

FIG. 16. Beech under the uniform system. Secondary stage well advanced; complete regeneration obtained. Harz Mts., Germany.

FIG. 17. Oak under the uniform system. Seeding felling just completed, one-third of the crop being removed. Forest of Bellême, Normandy.

in the case of hardy light-demanders with light and particularly winged seeds the seed-bearers may be widely spaced, the actual spacing being based on the distance to which the seed is scattered in quantity by a moderate breeze. Examples of seeding fellings applied to different species are given below (pp. 49–59). Where the opening of the canopy is likely to result in a rank growth of weeds or grass, or in the rapid drying or deterioration of the soil, the seeding felling should be carried out with caution. More cover should be retained on hot southerly and south-westerly slopes than on cool northerly slopes, particularly where the soil is dry or shallow. Where there is a matted growth of grass, it may be necessary to hoe or plough the ground at the time of a good seed-year, to enable the seed to reach the mineral soil. The admission of swine for a time before the seeding felling has an excellent effect in breaking up the soil. In coniferous forests the removal of a covering of undecomposed needles (raw humus) is often an essential aid to natural regeneration. In some types of forest, particularly in tropical and sub-tropical regions, the burning of the leaf layer has a beneficial effect on natural regeneration, and some species will not regenerate successfully otherwise. Under favourable conditions one seeding felling is sufficient, but if complete regeneration does not follow, it may be necessary to carry out a second when the next seed-year occurs.

Secondary Fellings, sometimes termed *removal fellings*. (Fr. *coupes secondaires*; Ger. *Nachhiebe*, *Lichtschläge*.) The object of secondary fellings is to remove the overwood and uncover the young crop in order to afford it more light, rain, and nourishment. When the young crop has been fully established as a result of the seeding felling, the overhead cover should not be retained a day longer than is necessary. Under the most favourable conditions an even-aged young crop, resulting from a single seed-year, should cover the whole regeneration area from end to end. Where this happens, in the case of a hardy light-demander the whole of the overwood may be removed in a secondary (in this case a final) felling within a few years of the seeding felling. In the case of a sensitive shade-bearer, however, the young crop should be uncovered more gradually by means of two or more secondary fellings carried out at intervals, in order that it may receive the protection from frost, drought, or other risks which the overwood affords; as the young crop develops it is thus gradually freed from protective cover, and many years may elapse before the last trees of the overwood are removed.

In actual practice, however, conditions are not always so favour-

able as those just described. The seeding fellings may result in successful regeneration in certain places and failure in others, in which case another seed-year, or more than one, may have to be awaited before regeneration appears over the whole compartment. In such a case the secondary fellings do not proceed with mathematical regularity: some parts of the compartment may be still in the seeding stage while others have reached various degrees of the secondary stage, and in places even the final felling may have been completed. Thus in carrying out secondary fellings *the state of the regeneration should be the chief guide towards the selection of trees to be felled or retained.* Where regeneration is sufficiently well advanced it should be freed from overhead cover, otherwise in the case of sensitive species it may be necessary to retain the cover a few years longer. The rule, in a nut-shell, is *follow the regeneration.* Hence where deciduous species are concerned, the marking of secondary fellings should always be done when the leaves are present, so that the young growth may be readily visible.

The last felling of all is termed the *final felling* (Fr. *Coupe définitive*; Ger. *Abtriebsschlag*, *Räumungshieb*, *Endhieb*). In the final felling all remaining seed-bearers are removed and the fully established young crop remains. After the final felling all blanks are restocked artificially, as a rule by planting. In the case of sensitive shade-bearers it may be necessary to plant up blanks early in the secondary stage, in order to afford protection to the young plants.

The number of secondary fellings and the interval between them vary greatly according to circumstances. With a hardy light-demander like Scots pine, if complete regeneration is secured in a single seed-year, only two regeneration fellings are usually necessary, the seeding and the final, the latter following the former at an interval of a few years. With a sensitive shade-bearer like beech, in which the young crop is uncovered gradually, or in cases where regeneration establishes itself with some difficulty, three or more secondary fellings, carried out at intervals over a number of years, may be necessary.

Remarks on Regeneration Fellings. When the old crop is opened out in successive regeneration fellings, the remaining trees respond by putting on enhanced increment ('light increment'). Hence both in the seeding and in the secondary fellings care should be taken to remove the defective trees wherever possible and to leave those with straight clean cylindrical boles; increment produced by the latter is of greater value than that produced by the former. In this way the quality of the remaining overwood becomes successively

better, until the finest trees of the crop are generally to be obtained from the later secondary fellings and the final felling.

A factor which affects the conduct of regeneration fellings in no small degree is the annual cut or yield, which is usually, though not invariably, fixed by volume. Circumstances must determine each year whether the prescribed volume shall be obtained from seeding or from secondary fellings or from both. When an area is first taken in hand for regeneration, every effort should be made to place as much of it as possible in the seeding stage, and hence at such a time the whole yield will generally be obtained from seeding fellings alone; where seed-years occur at somewhat long intervals it may even be advisable to exceed the prescribed yield during a good seed-year. As regeneration progresses the yield will be furnished mainly by secondary fellings.

In some cases the necessity for adhering to the prescribed yield may give trouble in that it interferes with correct silviculture. Thus if regeneration is backward, silviculture may require the overwood to be retained for seeding purposes or for the protection of the young crop, while questions of management require that fellings should be carried out to furnish the prescribed yield. Again, regeneration may have established itself in great abundance, and may be in urgent need of being freed by the removal of the overwood, whereas this if carried out might mean an outturn largely in excess of the prescribed yield for a year or two, followed by a corresponding drop in the outturn in the years following. Thus it is at times by no means easy to hold the balance between the respective requirements of silviculture and management.

Careless felling and extraction during the secondary and final stages may do much harm to the young growth. The chief precautions to be taken in order to minimize damage are (1) to fell and extract during the winter when there is deep snow on the ground, (2) to lop off the main branches or the whole crowns of trees before felling, (3) to make dragging or sliding paths at intervals through the young growth, and to use the same paths for the extraction of a succession of logs. In broad-leaved forest it is often customary after the final felling to 'cut back' damaged saplings in order to produce a regrowth of straight shoots. The lopping off of the crowns is a usual practice in some of the oak and beech forests of France, the object being partly to avoid damage to the young growth and partly to prevent the boles of the trees from splitting with the fall. For this purpose men ascend the trees with climbing irons and lop the crowns off with an axe (see Fig. 19).

In hilly country, in order to avoid damage by the sliding of timber through young growth, a compartment or a sequence of compartments is often worked over in such a way that regeneration commences at the top of a slope and proceeds in a downhill direction to the export road in the valley. In spite of the fact that considerable damage may be done to the young crop by the felling and extraction of timber, the young crop closes up and the results of such damage disappear in a remarkably short time.

As a precaution against wind damage, fellings sometimes begin in the east of the regeneration area and proceed towards the west. In parts of the Black Forest this procedure was introduced in the early part of the nineteenth century, and it developed afterwards into the shelter-wood strip system.

In modern practice it is sometimes customary to ignore the distinction between the different categories of regeneration fellings, and to regard these fellings as nothing more than a continuation of the process of thinning after regeneration has begun to appear. This idea is logical enough where much elasticity is allowed in regard to the areas in which regeneration is to be carried out and the period during which it is to be established; but where definite areas are set aside for regeneration in a given period of years, the recognition of the separate stages in the progress of regeneration is a great convenience, while there is also a marked distinction between the methods of executing the two main types of felling, seeding and secondary.

4. PERIODS AND PERIODIC BLOCKS

Period: Fr. *Période*; Ger. *Periode*, *Verjüngungszeitraum*.
Periodic block: Fr. *Affectation*; Ger. *Periodenfläche*.

Under the clear-cutting system we have seen that theoretically one coupe is cut and regenerated each year, so that if there are r years in the rotation (i.e. age of felling) there will be r annual coupes differing in age by one year. Under the uniform system this is impossible, since it requires more than one year to regenerate any given area. Hence, in order to systematize operations and ensure that the whole forest shall be felled and regenerated during the course of a rotation, the plan commonly followed under favourable conditions, such as those prevailing in many parts of France, is to divide the rotation into a number of *regeneration periods* and the forest into the same number of *periodic blocks*, each to be felled and regenerated in turn during the course of successive periods. For example, if the rotation is 100 years, divided into 5 periods of

20 years each, and if one whole rotation under the uniform system has just been completed, the normal distribution of age-classes should be as follows:

	AGE OF CROP	
Period and periodic block.	*At beginning of period (present time).*	*At end of period (20 years hence).*
I.	81–100	1 to 20*
II.	61–80	81–100†
III.	41–60	61–80
IV.	21–40	41–60
V.	1 to 20	21–40

* Old crop all removed; only young regenerated crop remains.
† To be regenerated during period II.

Length of Period. The period is the estimated number of years required to obtain complete regeneration over a whole periodic block and to establish this regeneration up to the time when the retention of the overwood is no longer necessary; it should begin with the seeding felling and end when the last remaining seed-bearers are removed in final fellings. It is necessary to distinguish between the actual time taken to regenerate small patches of forest and the absolute length of time usually taken to regenerate a whole periodic block. As a rule, the latter is considerably longer than the former, and it is the latter, not the former, which determines the length of the period. For example, in the oak forests of western France, thanks to favourable seeding conditions, the interval of time between the seeding and the final felling over small units of area may be only a few years, but the period is usually fixed at 25 years or more, in order to ensure the complete regeneration of a whole periodic block. The chief factors which determine the length of the regeneration period are as follows:

1. Seeding conditions. Where good seed-years are frequent, a shorter period is possible than where they occur at longer intervals.

2. Light requirements. In the case of light-demanders a short period is indicated; in the case of shade-bearing species a longer period may be adopted, as there is not the same necessity for uncovering the young crop rapidly.

3. Hardiness of species. Hardy species, which may be uncovered rapidly, require a shorter period than sensitive species, which may require the protection of the overwood for many years; of important European forest trees the two most sensitive, beech and silver fir, are also strong shade-bearers.

4. Climatic conditions. Where the climate is mild, the young crop, if it consists of sensitive shade-bearers, may be uncovered more rapidly than in localities subject to severe frost or drought, and the period may be shortened.

5. Soil and soil-covering. Where soil conditions are favourable to regeneration (e.g. sand and gravel for Scots pine, sandy loam for oak, absence of raw humus or heavy weed-growth for most species) the length of the period may be much curtailed. Where the soil is likely to dry up or where heavy weed-growth is to be feared, the canopy may have to be opened with caution during regeneration fellings, and the period is thus prolonged.

6. The question of mixtures. A long regeneration period tends to favour the more shade-bearing against the more light-demanding species: hence, other conditions being equal, a shorter period is indicated where light-demanders are to be favoured than where shade-bearers are to be encouraged.

7. Liability to injury. A long period for spruce is sometimes objected to on the ground that damage done during felling and extraction produces rot in the stems both of young and of old trees: a long regeneration period increases the risk of damage to the young crop and gives more time for the spread of rot in the old trees. This does not occur in the case of silver fir, for which species a longer period may be adopted.

8. Risk of fire. In some coniferous forests, even where hardy light-demanding species are concerned, a few seed-bearers are retained for many years after the young crop is established, as an insurance against fire, and the period is thereby prolonged considerably. This procedure is followed in the NW. Himalaya in some of the forests of *Pinus longifolia*, which are of an inflammable nature.

In deciding on the length of the period these various factors should be considered in relation to each other, with the object of arriving at a fair estimate of the time required to obtain complete regeneration and to establish the young crop beyond the risk of danger. In Europe it may be said that in the majority of cases the regeneration period varies from 20 to 30 years; this applies generally to oak, beech, and spruce, and often to silver fir if mixed with spruce. Where silver fir forms the bulk of the crop a long period—40 years or more—is frequently adopted, but in this case the system becomes the irregular shelter-wood system (p. 73) and can no longer be called the uniform system. In the case of pure Scots pine the period is generally from 4 to 10 years.

Theoretically speaking, the periodic block should be completely

regenerated by the end of the period. Actually it often happens that owing to various causes regeneration has not established itself as quickly as was hoped, and some areas may be still in the secondary or final stage at the end of the period. In this case there is generally no delay in beginning regeneration in the periodic block next in order, while the arrears of fellings in the previous block are worked off separately. In some cases, if a periodic block is not completely regenerated by the end of the period the remaining seed-bearers are felled and regeneration is completed artificially.

It will be apparent, therefore, that the period represents only an estimate of time, which may or may not prove to be accurate, and which frequently has to be departed from in practice. Hence the idea of definite periods of stated length, although it persists under the favourable conditions prevailing over a part of France, has been abandoned, or has never been recognized, in certain other parts of Europe, particularly in those regions where conditions for regeneration are not of the most favourable or where storms and other calamities are apt to upset calculations. In the latter case a rough estimate of the time taken to regenerate a given area is usually made for the purpose of calculating the yield, but the idea of definite periods for the regeneration of periodic blocks does not exist. In such regions, again, compartments allotted for regeneration may be already partly regenerated with advance growth in gaps, and the regeneration period will represent only the time required to complete the regeneration. In some cases the period—not actually expressed—varies considerably from place to place, according to the nature of the crop, even within the same compartment, a longer period being adopted where shade-bearers prevail than where the bulk of the crop consists of more light-demanding species.

The length of the regeneration period has a decided effect on the form of the young crop. Short periods produce even-aged young crops, while the longer the period the more uneven-aged does the crop become.

Nature of Periodic Blocks. There are considerable differences in the manner in which periodic blocks, if recognized at all, are constituted. When the uniform system was developed in France in the middle of last century, the procedure followed was to divide each series (i.e. complete working unit of forest) into as many large *self-contained periodic blocks* as there were periods in the rotation. These periodic blocks were allotted once for all, each to its respective period. This arrangement, which is still in force in many of the oak and beech forests and some of the coniferous forests of France,

possesses certain advantages. Operations of different kinds—timber fellings, thinnings in pole crops, cleanings in young crops—are each carried out over self-contained areas of some extent; this facilitates supervision of felling and extraction and tends towards economy of working owing to the concentration of such operations in compact areas. In some of the coniferous mountain forests of Austria large self-contained regeneration areas are adopted with the view of justifying the cost of constructing ropeways and other special export works for the extraction of large quantities of timber from one place.

But the formation of fixed self-contained periodic blocks, and their allotment to all the periods of the rotation, has the great disadvantage that in regions subject to storms, insect ravages, and other calamities, this arrangement cannot be maintained for long. From time to time portions of the area are damaged or destroyed, and require to be regenerated; this at once throws out the preconceived arrangement, and if such calamities occur with any frequency the periodic blocks lose their identity and have to be abandoned.

The formation of large self-contained periodic blocks also presents difficulties from the management point of view, in that it usually involves the artificial allotment to definite periods of at least some crops which may be either too young or too old for the period to which they have to be allotted. In the one case they come under regeneration before their time and in the other they have to be retained until they are past maturity; in either case, apart from economic disadvantages, natural regeneration may be rendered difficult. The difficulty as regards the allotment of crops to large periodic blocks according to age can be got over to a great extent by forming *scattered periodic blocks*, that is, each compartment or even sub-compartment is considered separately and allotted to its appropriate period. This procedure is followed in a good many European forests, and there is a tendency to extend its use in place of the self-contained periodic block arrangement. In introducing the uniform system, it may not always be advisable to allot all crops to definite periods in advance, in which case allotment is made to period I (to be regenerated first), and often to one or more other periods in addition.

The formation of permanent periodic blocks, whether self-contained or scattered, is practicable only where there is little or no risk of serious danger from storms or other calamities; hence this procedure is followed in regions where the climate is not severe, particularly in the case of broadleaved forests, which are less subject

to such dangers than coniferous forests. But wherever such risks are prevalent, the idea of forming permanent periodic blocks, and allotting crops to definite periods in advance, has had to be abandoned. Thus in the coniferous forests of the hilly regions of Central Europe, where severe storms are not infrequent, fixed periodic blocks are not recognized. Instead of this, when a working plan is revised, the areas to be placed under regeneration during the interval between that revision and the next one are decided on according to the state of the crop and marked on the map. Regeneration fellings are carried out in these areas, and by the time the next revision takes place, say 10 years later, certain of the areas may have been completely regenerated, while others are still under regeneration. The latter will be retained as regeneration areas under the revised working plan while new areas will be taken up for regeneration and added to them in place of the areas already regenerated. The same procedure is followed at each revision in turn, so that there are always certain areas under regeneration, though these are periodically changing; this in fact amounts to what may be termed a *floating periodic block*. This procedure was introduced into some of the coniferous forests of the French Jura and Vosges in 1894, in supersession of the arrangement of fixed periodic blocks. Here it goes by the name of the *quartier bleu* method, because the areas placed under regeneration for the time being are marked blue on the map, while the rest of the forest remains uncoloured and is termed the *quartier blanc*. In certain cases the areas to be placed under regeneration next in order are coloured yellow, and are termed the *quartier jaune*.

Even where there are no serious calamities to be feared, fixed periodic blocks may be impracticable on the ground that natural regeneration may not always be obtainable when and where it is desired, although in certain places it may appear spontaneously in great abundance without deliberate aid from man. In such cases the procedure indicated is to follow regeneration rather than to attempt to force it. Ash and sycamore show this tendency to some extent in England, but it is in the tropics, where the silviculture of the various species has not yet been fully studied, that the principle of the floating periodic block should be specially applicable, and it is, in fact, now being applied to some of the sal forests of India (see p. 57).

Where regeneration takes place rapidly and regularly, periodic blocks are sometimes dispensed with, and an arrangement of annual coupes may be followed similar to that of the clear-cutting system.

Thus in some of the Scots pine forests of Normandy seeding fellings are made in regular annual coupes by area; regeneration generally establishes itself readily, and a few years after the seeding felling the seed-bearers are removed in one or two secondary fellings (see pp. 53 and 54). The yield is fixed entirely by area, but the annual volume outturn is reasonably constant because the secondary fellings follow the seeding fellings with sufficient regularity.

A similar procedure is exemplified in the Aleppo pine (*Pinus halepensis*) forest of Gemenos on the south coast of France. The rotation is 60 years, and each series contains 60 corresponding annual coupes (compartments). The regeneration fellings are two in number, a seeding felling removing about 50 per cent. of the crop followed by a final felling which removes the remainder 10 years later. Thus two compartments are worked over each year, one by a seeding and one by a final felling. The pine seeds as a rule annually, but since regeneration does not always establish itself readily on the dry calcareous soil of that region, full use is made of heavy thinnings to stimulate regeneration in advance.

The following classification summarizes the methods of adapting the uniform system to periodic blocks or otherwise:

1. Fixed periodic blocks:
   (*a*) Self-contained.
   (*b*) Scattered.
2. Floating periodic blocks, usually scattered.
3. Annual coupes by area.

Numbering of Periods and Periodic Blocks. When periods and periodic blocks are fixed, the practice in France is to number them I, II, III, &c., and to retain these numbers permanently. Thus in the oak forest of Bellême (Orne), when this system was introduced in 1856, the rotation was fixed at 200 years and divided into 8 periods of 25 years each. This has been adhered to ever since, so that in 1927, for instance, the ages of the crops in the periodic blocks already regenerated were theoretically as follows:

Period.		*Age of regenerated crop in* 1927.
I.	1856–1880	47–71 years
II.	1881–1905	22–46 years.
III.	1906–1930	up to 21 years.

The year 1927 was the 22nd year of the 3rd period, and in that year the crops in periodic block III should have been in the final stage or already regenerated. In the ordinary course the remaining periodic blocks would be due for regeneration during

subsequent 25-year periods, from period IV (1931–55) to period VIII (2031–55).

Sometimes, however, as in parts of Germany, the numbers are altered whenever a new period begins, so that I always represents the periodic block under regeneration, II the next in order, and so on; or in other words, when a new period begins, II becomes I, III becomes II, and so on, while block I, in which regeneration has just been completed, receives the last number of the series.

5. FORM OF CROP PRODUCED

The ideal of the uniform system is to produce young crops as even-aged as possible. We have seen that the crop becomes more and more uneven-aged with the lengthening of the period. A stage is at last reached at which the uniform system gives place to the irregular shelter-wood system; ordinarily the dividing line is reached when the period is between 30 and 40 years, although the form of the young crop rather than the length of the period is the best criterion. With periods up to 30 years unevennesses in the young crop due to differences of age tend to disappear during the pole stage, and by the time the tree stage is reached the crops have all the appearance and characteristics of even-aged crops, with long clean cylindrical boles.

6. UNIFORM SYSTEM WITH ARTIFICIAL REGENERATION

The uniform system with artificial regeneration is sometimes employed for the purpose of introducing new species or increasing the proportion of some particular species already existing in insufficient quantity. Except that the young crop is introduced artificially by sowing or planting, the procedure is similar to that followed in the case of natural regeneration, the canopy being opened gradually or rapidly according to the light requirements and hardiness of the young crop, and the degree of risk of frost, drought, heavy weed-growth, or other injurious factors. Generally, however, a shorter period may be adopted than in the case of natural regeneration, since an artificial crop can be established more rapidly. Artificial regeneration under a shelter-wood is employed most commonly either for the introduction of sensitive shade-bearers or in order to obtain a mixture by combining the artificial regeneration of introduced species with the natural regeneration of existing species. Under certain conditions species which are at least tolerably light-

demanding may be introduced under a shelter-wood, as in the case of oak in the Spessart (see p. 52).

7. ADVANTAGES AND DISADVANTAGES OF THE UNIFORM SYSTEM

The chief advantages and disadvantages of shelter-wood systems in general (see p. 29) apply in the main to the uniform system. The following apply more particularly to the uniform system in comparison with other shelter-wood systems:

ADVANTAGES: 1. The fellings are simpler in execution than in most shelter-wood systems: the seeding felling in particular involves a straightforward even opening of the canopy over large areas, after the manner of a thinning.

2. Crops of an even-aged type are produced, with tall clean cylindrical boles; in this respect the uniform system, like the other more or less even-aged systems, is superior to the selection system.

DISADVANTAGES: 1. Damage to young growth by felling and extraction is greater than in the case of strip or wedge fellings, although by taking the precautions already indicated it may be reduced considerably.

2. The mother trees isolated in seeding or secondary fellings are liable to be thrown by wind, more especially if crown and root development has been insufficiently promoted during the thinning stages. Shallow-rooted species like spruce are particularly susceptible in this respect.

3. In hot situations isolated seed-bearers of thin-barked species like beech are liable to suffer from sun-scorch.

4. In localities subject to frost or drought overhead cover, such as is obtained by the uniform system, is a less efficient safeguard against damage from these causes than side protection such as is secured by the strip system.

5. In localities where damage by storms or snow is prevalent, the even-aged crops produced by the uniform system are more subject to damage than the more uneven-aged crops produced by the group system, the irregular shelter-wood system, or the selection system.

Generally speaking, it may be said that where there are no severe climatic conditions with which to contend, and where conditions of seeding and regeneration are favourable, the uniform system, owing to its simplicity, has a special advantage over most of the other systems. It is not so well adapted for regions where serious damage by storms or snow is to be feared, or where seeding or soil conditions are unfavourable.

8. TREATMENT OF INDIVIDUAL SPECIES AND MIXTURES

In applying the uniform system to individual species, considerable variations in the treatment are necessary in order to provide for differences in light requirements, hardiness, and other characteristics of the species in question. In the case of mixtures the problem of regeneration becomes more complicated. It is the exception rather than the rule to find two species regenerating with equal freedom and vigour; in the majority of cases special measures have to be taken to hold the balance between the two, and if necessary to assist the one against the other. Where one species is more light-demanding than the other, the course most commonly adopted is first to open the canopy slightly and obtain partial regeneration of the more shade-bearing species, then to open it more heavily by the removal of seed-bearers of that species in order to allow the more light-demanding species to regenerate and fill the gaps. If there is a third and still more light-demanding species in the mixture, a further opening of the canopy is made subsequently, seed-bearers of the light-demander being retained somewhat in the form of standards, in order to regenerate any blank spaces remaining.

Although the procedure just described is the normal one, it has to be modified to suit special cases. Thus where one species tends to become dominant at the expense of the others, it is generally necessary to establish the latter first in groups round seed-bearers of the species concerned, or even to introduce them artificially to the extent desired; the dominant species is regenerated afterwards, generally by a uniform opening of the remainder of the canopy.

The following examples will serve to demonstrate the application of the uniform system to individual species and mixtures:

Beech. A shade-bearer with a heavy seed which does not spread naturally to any distance from the parent tree. Full mast-years occur on an average every 5 or 6 years in mild climates such as that of western France, and every 8 to 12 years in most parts of Germany, apart from occasional partial mast-years. At its higher elevations the beech does not seed abundantly more than once in about 15 years. Beech seeds more irregularly than most European species. Partial seeding can be utilized to a greater extent than in the case of more light-demanding species, since the seedlings can persist for some time under shade, and the patches of partial regeneration can be used as a nucleus for more complete regeneration later. The seedlings are sensitive to frost and drought, and do not tolerate acidity or swampiness in the soil. A thick layer of undecomposed

leaves is unfavourable, in preventing the radicle from reaching the mineral soil. Conditions for regeneration are favourable when a light growth of herbaceous or shrubby vegetation is beginning to appear; one of the best indicators of favourable light and soil conditions is the wood sorrel (*Oxalis acetocella*). A thick matted growth of grass, such as may follow too heavy an opening of the canopy, prevents regeneration. *Aira flexuosa*, which is sometimes common in beech forests, is one of the worst grasses in this respect. Such a matted soil-covering may be broken up by ploughing or by the admission of swine.

As a rule the regeneration period varies from 20 to 30 years. Often seeding fellings are made irrespective of the occurrence of seed-years. Where seed-years are awaited, when the flowers of the beech in spring give promise of a good mast a cutting plan is usually prepared in summer so that as large an area as possible may be marked in time for felling to be carried out the following winter.

Generally more than one seeding felling is necessary in order to effect complete regeneration. The seeding felling is a light one, the canopy being opened only to such an extent that the crowns of the trees touch when swayed by the wind. In the beech forests of France 25 to 30 per cent. of the crop is removed, leaving about 70 trees per acre under average conditions (see Fig. 13). Any under-story or undergrowth of shrubs and suppressed trees should be removed. Fig. 14 shows the seeding stage well advanced.

The secondary fellings begin when the young crop is knee high (6 to 8 years old) and should be cautious and gradual. Under the most favourable conditions there are generally at least three, including the final felling. Trees with large spreading crowns should be removed early, as they drain the ground, depriving seedlings of nourishment and thus preventing regeneration.

The final felling should not be delayed longer than is necessary; isolated beech trees tend to become sun-scorched, while the damage done during felling and extraction is intensified where the young crop is allowed to grow too tall. Fig. 16 shows a beech crop in the secondary stage, and Fig. 15 shows a crop 60–70 years old produced by this system.

Hornbeam is a frequent companion of the beech in the forests of France. It seeds freely every two or three years, and regenerates in great profusion; in order to favour the beech, it is necessary to keep the canopy dark enough during the seeding stage to kill off the hornbeam seedlings, which stand less shade than those of the beech.

FIG. 18. Oak under the uniform system. Seeding felling just completed. Note absence of undergrowth owing to close canopy. Forest of Bellême.

FIG. 19. Oak under the uniform system. Final felling in progress, with topped trees. Natural regeneration (leafless) well established. Note man up tree in right centre. Forest of Bellême.

FIG. 20. Oak under the uniform system. Young natural crop 25 years old, showing characteristic density. Forest of Bellême.

FIG. 21. Uniform system with artificial regeneration. Beech wood in foreground opened out and undersown with oak in lines 1 metre apart. Young oak crop 10 years old, raised by similar sowings, behind. Old unregenerated beech wood in background. Spessart, Bavaria.

Oak. A light-demander with a heavy seed which does not spread naturally to any distance from the parent tree. As a rule regeneration springs up more readily on sandy loams than on compact clay soils. The periodicity of good mast-years varies greatly according to the mildness or severity of the climate. In the mild climate of the Adour valley in south-western France, annual seeding of the pedunculate oak is the rule. In Normandy and in western and central France generally, good seed-years of sessile oak may be expected every 4 to 8 years. In the more severe climate of north-eastern France they are far more infrequent. On the plateau between the Moselle and the Meurthe the oak seeds well on an average only at intervals of about 20 years. Writing in 1919, Huffel stated that in Lorraine there had not been a copious mast-year since 1865 and 1868. Under such conditions the uniform system is out of the question. In the Spessart, Bavaria, full mast-years of sessile oak occur on an average every 10 to 12 years. Oak seedlings, though less sensitive than those of the beech, suffer in frosty localities.

Under the favourable conditions prevailing in western France, complete regeneration is not infrequently secured in 6 to 10 years, this being actually the interval of time between the seeding and the final felling. Nevertheless the regeneration period for whole periodic blocks is sometimes much longer, because it takes some years for seeding fellings to be completed over a whole periodic block. In the forest of Bellême it is 25 years, in the forest of Bercé as much as 36 years.

As a rule about one-third of the crop is removed in the seeding felling, about 30 to 50 seed-bearers per acre being left, according to age and size, and there is thus a space of several feet from crown to crown. All undergrowth and low cover should be removed. In France seeding fellings are generally made irrespective of mast-years; when a good mast-year occurs the ground is often thickly carpeted with seedlings, in which case the secondary fellings follow rapidly. Generally speaking there are two secondary fellings, including the final felling, but under favourable conditions a single final felling is carried out a few years after the seeding felling. Figs. 17, 18, and 19 show oak crops in the seeding and final stages. Where frost is feared the canopy is opened more cautiously, both in the seeding and in the secondary fellings. The young crops are kept in a dense condition (see Fig. 20), cleanings being carried out at an age of about 20 to 25 years, and thinnings being begun when the crop is 30 years old or more.

Oak and Beech. This mixture is a common one wherever these

two species occur on the continent of Europe; in fact it may be considered exceptional to find an oak forest without a mixture of beech, which is maintained partly for soil-protection purposes. In localities specially favourable to oak, as in western France, this species usually holds its own against the beech, and a successful mixture can generally be obtained by carrying out regeneration fellings in the ordinary way, as described for oak. Where, as frequently happens, the beech regenerates with greater freedom and tends to outgrow and suppress the oak in youth, care should be taken during the thinning stages to develop a large percentage of good oak seed-bearers. It is also advisable to await an oak mast-year before carrying out the seeding felling, which should be made open enough to effect oak regeneration. The removal of the overwood in secondary fellings should proceed as rapidly as circumstances will permit, and if necessary the young beech should be cut back or topped where it tends to suppress the oak. Where oak mast-years are very infrequent the uniform system with natural regeneration is out of the question.

In the Spessart special measures are taken to increase the proportion of oak by introducing it artificially under a shelter-wood of beech. Both species occur naturally in this region, the oak being of the sessile variety. The proportion of oak obtained by natural regeneration, however, is insufficient, and steps are therefore taken to increase the quantity of this species at the expense of the beech, which regenerates freely, grows more rapidly in youth, and would oust the oak if permitted to do so. The procedure adopted is to open out the crop heavily, about two-thirds of the growing stock being removed, and to introduce oak by sowing acorns under the light cover of the open beech wood, which is retained to protect the young seedlings against frost and drought, to retard weed-growth, and to promote a mixture of beech by natural regeneration. The beech overwood is removed in secondary fellings at intervals of 2 or 3 years, the final felling being carried out within 8 years of the seeding felling and the sowing of the oak. From the time the oak sowings are carried out the young beech has to be uprooted or cut back where necessary to prevent its becoming dominant. The regeneration of a whole compartment is completed in this way in a period of 20 to 30 years, involving as a rule two or three beech seed-years. This method of regeneration is illustrated in Fig. 21.

The effect of a long regeneration period in favouring beech against oak has been demonstrated in the mixed oak and beech forests of the Wienerwald, Austria. Here the uniform system was

FIG. 22. Scots pine under the uniform system. Seeding stage, with about 35 seed-bearers per acre. Forest of Rouvray, Normandy.

FIG. 23. The same. Final stage. Fellings completed in foreground; a few seed-bearers remaining behind. Forest of Roumare, Normandy.

FIG. 24. Spruce and silver fir under the uniform system. Natural regeneration, with silver fir leading and spruce filling the gaps. La Joux, French Jura.

introduced early last century with a period of 30 years, the result being that the mixed crops were superseded by almost pure beech; the period was therefore subsequently shortened to 15 years, or in places less, in order to encourage the oak.

Scots Pine. A strong light-demander with a winged seed which is carried by wind to some distance from the parent tree. As a rule a certain amount of seed is produced almost every year, and good seed-years occur at intervals of 3 or 4 years. In the case of the Scots pine, as of many other pines, crown development is an important factor in the production of an abundant supply of cones.

The seedlings, which are hardy as regards frost and drought, will not tolerate shade. Regeneration generally springs up in abundance on sandy and gravelly tracts, and in dry places a moderate soil-covering of heather or low open bracken or broom is a help rather than otherwise, in preventing excessive drying of the soil. Regeneration is greatly stimulated by the raking off of the needle layer and the exposure of the mineral soil.

The Scots pine is well adapted for the uniform system if care is taken to encourage the development of the crown and the root system by means of regular thinnings at intervals of not more than 5 years; failing this the trees, when isolated by the seeding felling, are apt to be thrown by wind. In applying the uniform system the procedure is simple. The seeding felling consists of a wide spacing of seed-bearers, and a final felling should follow when the young crop is not more than 1 foot high, that is, within a few years of the seeding felling.

Examples of such open seeding fellings and short regeneration periods may be seen in some of the Scots pine forests on the dry sands and gravels of the Seine valley. These forests are of artificial creation, the pine having been introduced to replace the pre-existing poor crops of oak and other hardwoods. The seeding felling consists of the removal of 75 to 80 per cent. of the crop and the retention of 30 to 35 seed-bearers per acre, and the final felling as a rule follows in 3 to 5 years, by which time regeneration should be well established (see Figs. 22 and 23). Where regeneration is incomplete a few seed-bearers may be retained for two or three years more, but it has been found that if regeneration does not appear rapidly it will probably not come in at all, and hence where it fails it is usual to sow up the blanks without delay. The spacing adopted in the seeding fellings was arrived at after actual trials, in the course of which it was found that a closer spacing hindered regeneration. In the forests in question the isolated seed-bearers are frequently

thrown by wind, owing largely to the fact that insufficient attention has been given in the past to the production of wind-firm trees by suitable thinnings. Similar open seeding fellings are practised in the Auvergne.

In the State Forest of Isenburg in Hesse-Darmstadt good results have been obtained with a short regeneration period. Here there are ordinarily three regeneration fellings. About one-third of the crop is removed in the seeding felling, which generally begins where there is already a crop of seedlings on the ground. The secondary and final fellings follow at short intervals, and good results have thus been obtained with a regeneration period varying from 6 to 9 years. The raking of litter by right-holders stimulates regeneration.

Spruce. A moderate shade-bearer with a light winged seed which is conveyed by wind to some distance from the parent tree. Seed-years, although fairly frequent, are somewhat irregular; they occur on an average at intervals of 3 to 10 years. The seedlings are fairly frost-hardy but are sensitive to drought owing to their shallow root-systems; in moist soil they sometimes spring up in great abundance. They do not tolerate heavy shade, nor do they recover satisfactorily after suppression. In Central European countries raw humus is one of the greatest obstacles to regeneration; the raking off of the undecomposed needle layer produces conditions favourable to germination and the establishment of the seedlings.

The uniform system is unsuitable for spruce except in localities which are not subject to gales, since this shallow-rooted species, when opened out in regeneration fellings, is too liable to be thrown by wind. For this reason, if the uniform system is to be applied with success it is essential that the conditions for regeneration should be entirely favourable, so that the young crop may be established rapidly. Hence the seeding felling should preferably be carried out in a good seed-year: experience has shown that it should be made cautiously, in order to avoid isolating the trees and exposing them to wind damage. At the same time sufficient light should be afforded to promote regeneration; this can be effected by the removal of one-quarter to one-third of the growing stock. The final felling should be carried out within 4 or 5 years, with or without an intervening secondary felling, and blanks should be regenerated artificially.

In Central Europe the uniform system for spruce has been largely given up in favour of combinations of systems (strip, group, &c.) in which uniform fellings sometimes play a part. Here the

spruce is very commonly treated in mixture with silver fir with or without beech, Scots pine, and larch.

Silver Fir. A strong shade-bearer with a somewhat heavy winged seed, which is conveyed by wind to some little distance from the parent tree, but not so far as that of the spruce. Good seed-years occur on an average every 2 to 10 years according to locality; under favourable conditions seeding is frequent and regular. The best regeneration is obtained as a rule from trees 90 to 120 years of age. The seedlings are sensitive to frost and drought and are readily browsed by deer; they stand a considerable amount of shade, and have good power of recovery after suppression.

The silver fir can be treated successfully under the uniform system. There are often quantities of seedlings on the ground before any seeding felling is carried out, and the secondary fellings may begin forthwith. Where a seeding felling is carried out it should consist mainly of the removal of any under-story and the heightening of the canopy, but with only a slight opening of it. The secondary fellings should be carried out with caution, and there should be several of them extending over a period of several years; the young crop requires protection till it is well established, and the cover should be removed gradually.

Spruce and Silver Fir with other Species in Mixture. In mixed crops of spruce and silver fir, in many of which beech and Scots pine also occur, the procedure generally followed is to carry out a very cautious seeding felling and allow the silver fir to establish itself; if beech is present it tends to appear in groups round beech seed-bearers. A few years later the canopy is opened sufficiently to enable the spruce to regenerate, spruce and Scots pine seed-bearers being retained and silver fir and beech being removed where possible. As soon as the spruce has regenerated itself sufficiently, the canopy is still further opened in one or more secondary fellings, scattered Scots pine seed-bearers being retained during the final stage to seed up any gaps. The mixture can be regulated by the rate at which the canopy is opened. A gradual opening encourages the silver fir and beech, while a more rapid opening encourages the spruce and Scots pine.

In some of the forests of the French Jura, spruce and silver fir in mixture are treated successfully under the uniform system. Regeneration of silver fir often appears in abundance before the canopy is opened out at all, and persists for some time under the heavy shade. A seeding felling is then made in the interests of spruce, followed by either two or three secondary fellings, including the

final felling. Regeneration is thus completed within 20 years, although the period laid down for the regeneration of whole periodic blocks may be as much as 30 years or more. While it is desirable to complete the regeneration fellings as rapidly as possible, owing to danger from wind, care is necessary to avoid too sudden an opening of the canopy, which may result in the death of the pre-existing silver fir seedlings. Fig. 24 shows successful regeneration obtained in this manner. In the regeneration of silver fir, groups of advance growth are retained, and hence the young crop often has an irregular appearance for a time. Where deer are prevalent the silver fir regeneration may fail to make any headway until the spruce has established itself and formed a protective cover for the fir.

Chir Pine (*Pinus longifolia*).[1] In the NW. Himalaya the uniform system was first applied to the chir pine in 1895, since when it has been extended to various localities with considerable success. This gregarious tree, which is strongly light-demanding, forms extensive forests on hot dry slopes, chiefly between 2,000 and 7,000 feet elevation. The average periodicity of good seed-years varies from 2 to $3\frac{1}{2}$ years according to locality. The winged seed is carried by wind to some distance from the parent tree, and with a suitable distribution of seed-bearers with good crowns natural regeneration usually springs up in abundance on well-drained porous soils with a good proportion of sand and fine mica, where the root-system of the seedling develops well; on stiff clay soils and on shallow soils overlying limestone, where the root-system cannot develop sufficiently, regeneration may fail on hot aspects owing to excessive insolation. Regeneration is stimulated by the burning of the thick covering of coarse undecomposed needles which is often present, but as soon as the seeding felling is made strict protection from fire is essential to success. It has been found in general that a seeding felling by which about 5 to 8 good seed-bearers per acre are retained will effect complete regeneration, but on hot aspects it may be advisable to leave considerably more. So far as the light requirements and the hardiness of the seedlings are concerned, the seed-bearers should be removed as soon as sufficient regeneration has appeared, but since the fire menace is always present, the precaution is sometimes taken to retain a few seed-bearers as an insurance

[1] A detailed account of the regeneration and treatment of this tree will be found in *The Silviculture of Indian Trees*, vol. iii, pp. 1061–8 and 1071–4 (Oxford, Clarendon Press, 1921), and in *Indian Forest Memoirs*, Silviculture Series, vol. i, Part I (Calcutta, Supt. Govt. Printing, India, 1916). See also *Practical Forest Management*, by C. G. Trevor and E. A. Smythies, pp. 128–30 (Allahabad, Govt. Press, 1923).

FIG. 25. *Pinus longifolia* under the uniform system; final stage. Remaining seed-bearers being tapped for resin. NW. Himalaya.

FIG. 26. Deodar, blue pine, and spruce under the uniform system. Natural regeneration resulting from a spacing of 20 seed-bearers per acre. NW. Himalaya.

against fire until the young crop is reasonably safe from destruction. For this purpose regeneration periods up to 35 years are in force. Fig. 25 shows a crop in the final stage with these 'insurance' trees standing.

The striking similarity in habit and environment between the Himalayan chir pine and the western yellow pine (*Pinus ponderosa*) of North America would seem to indicate that similar treatment would be successful in the case of the latter species.

Other Himalayan Conifers. Of other Himalayan conifers the deodar (*Cedrus Deodara*) and the blue pine (*Pinus excelsa*) are worked successfully under the uniform system.[1] The blue pine is a strong light-demander from youth upwards; the deodar stands rather more shade and the seedlings require protection from drought on hot dry slopes. Both species are frequently found in mixture, the spruce (*Picea Morinda*) sometimes occurring with them. The blue pine seeds freely, on an average more than once every two years, and the winged seeds are distributed to long distances from the parent tree. The deodar seeds well on an average once in three years, the winged seeds being disseminated to a moderate distance.

The deodar being more shade-bearing than the blue pine, it is possible to obtain a satisfactory mixture in regeneration fellings by first opening the canopy to about 20 to 30 seed-bearers per acre; when sufficient regeneration has been obtained, a further opening of the canopy to 5 to 10 blue pine seed-bearers per acre should complete the regeneration of the latter species. Fig. 26 shows regeneration in progress in this type of forest. In pure blue pine forest a spacing of 8 to 12 seed-bearers per acre has been found to give abundant regeneration, the number being increased to 20 on hot dry slopes. The spacing adopted in seeding fellings should vary with aspect and other factors, but actually where soil conditions are favourable regeneration often springs up in great profusion under various degrees of spacing. In the case of the blue pine, profuse regeneration generally takes place on the introduction of fire-protection in previously burnt tracts. In the case of the deodar, regeneration is stimulated by the raking of litter, the burning of refuse, or the hoeing of the soil round seed-bearers.

Sal (*Shorea robusta*). The uniform system in one form or another is being extended in the sal forests of India, particularly in the United Provinces. This gregarious tree, a moderate light-demander,

[1] For details the reader is referred to *Practical Forest Management* by Trevor and Smythies, pp. 125–8, and to *The Silviculture of Indian Trees*, vol. iii, pp. 1026–9 and 1030–2 (*Pinus excelsa*) and pp. 1109–14 and 1119–23 (*Cedrus Deodara*).

tends to regenerate in even-aged masses. Natural regeneration springs up in great profusion in certain places, though the seedlings may die back repeatedly for many years before establishing themselves; in other places regeneration may fail entirely owing to a combination of factors. The plan adopted, therefore, is to take advantage of regeneration already present and to free it, rather than to rely on obtaining it in places where it has not yet established itself. The system as applied varies in detail, but generally speaking areas are allotted for regeneration not only according to the age of the old crop but also according to the quantity of regeneration already present and in need of freeing from overhead cover.

In periodic block I the usual procedure is to leave a shelter-wood for a time as a protection against frost, and to clear-cut everything else. After the extraction of all saleable material the refuse is burnt and regeneration is secured from coppice shoots springing largely from suppressed advance growth which has been cut back. The young crop is cleaned as required, and the coppice shoots are thinned from time to time until only one is left per stool, so that by the time the pole stage is reached the crop is in the condition of even-aged high forest; trees obtained in this way are found to be as good as those obtained from seed. In periodic block II the operations consist of thinnings or preparatory fellings, burning the leaf layer, and hoeing the soil with the object of obtaining seedling regeneration in the state of suppressed advance growth. In view of the uncertainty of obtaining regeneration exactly where it is required, any hard and fast allotment of crops to periods is usually impracticable. The proper course is to follow regeneration and to employ a floating periodic block.

The procedure followed in the case of the sal is also indicated, with suitable modifications, for other dipterocarps of the dry forest type, such as the Burmese *Dipterocarpus tuberculatus*, *Pentacme suavis*, and *Shorea obtusa*.

Tropical Rain Forest. In some of the evergreen rain forests of the Malay Peninsula regeneration under the uniform system is practised with success. This type of forest is characterized by the large number of component species, of which only a portion may be marketable, and by the great luxuriance of the vegetation. The most characteristic trees are the dipterocarps, of which there are over 100 species. Some of the more valuable species regenerate freely, and the seedlings are capable, in varying degree, of persisting for a time under shade, though they die off unless the canopy is opened. Caution is generally necessary in opening the canopy,

owing to the danger of promoting a heavy growth of grass, weeds, and climbers.

There is usually no difficulty in regenerating the more valuable species if there is a sale for the inferior kinds, otherwise the work is somewhat costly. The procedure generally followed is to open the canopy by removing the inferior species ; this benefits seedlings already present and induces further regeneration of valuable species from the seed-bearers retained. Wherever regeneration is established the overhead cover is removed rapidly, and cleanings are carried out where there is a danger of suppression from weeds, climbers, and inferior species.

In order to secure regeneration of the desired species in sufficient quantity, a procedure which has had successful results, particularly in the case of camphor (*Balanocarpus Heimii*), is to carry out repeated improvement fellings in which inferior species are removed. This induces a dense regeneration of this species, as many as 3,000 young plants having been counted on an acre. The improvement fellings are then followed by regeneration fellings for the removal of the overwood and the establishment of the young crop.

Experiments have resulted in successful regeneration on somewhat similar lines in the evergreen forests of Western India and the monsoon forests of Burma. The cost of weeding the young crop, however, may prove an obstacle to the adoption of this form of regeneration in many localities.

9. APPLICATION OF THE UNIFORM SYSTEM

Systems of regeneration resembling the uniform system as now practised appear to have been known over 400 years ago. In Germany there are records dating from the end of the fifteenth century in which reference is made to regeneration over large coupes, producing even-aged crops. In the Forest Ordinances of the fifteenth and sixteenth centuries, rules are laid down regarding the number of seed-bearers to be retained with the object of securing natural regeneration. Many writers during the eighteenth century make reference to natural regeneration obtained by leaving seed-bearers, and the Hesse-Kassel Ordinance of 1761 prescribes, among other things, fellings similar to those of the uniform system. In Hungary an Ordinance of 1565 prescribes, among other matters, the order of fellings and the reservation of seed-bearers.

In France the idea of coupes by area, leaving a specified number of trees for seeding purposes, took shape at least as early as the

fourteenth century, and led subsequently to the adoption of the *tire et aire* system (see p. 125). The latter system had points of resemblance to the uniform system, which began to be introduced in place of it before the middle of last century. The old *tire et aire* system, in fact, may be regarded as the forerunner of the uniform system. Between the fourteenth and the nineteenth centuries mention is made from time to time, in various ordinances, of the reservation of trees to act as seed-bearers under different conditions. As early as 1520, Tristan de Rostaing, one of the grand masters and head of the Forest Service, recommended a form of successive regeneration fellings to replace the *tire et aire* system. It is clear, therefore, that in France something closely resembling the uniform system of to-day was thought of, if not actually practised, at least four hundred years ago. In the Sihlwald in Switzerland it is believed that regeneration fellings somewhat on the lines of the uniform system have been in operation for five hundred years.

The uniform system in its modern application, however, will always be associated with the name of G. L. Hartig (1764–1837), who as Director-General of the Prussian State Forest Service (1811–37) had a great influence on the silviculture of his time, and strove to introduce regular order everywhere. The first edition of his *Anweisung zur Holzzucht* appeared in 1791, and marked the beginning of a new epoch. Hartig, acting on experience gained in oak and beech forests under favourable conditions of soil and climate in Darmstadt and the Wetterau, advocated even-aged regeneration over areas as little scattered as possible, in order to facilitate the supervision of fellings. He recognized three regeneration fellings: (1) *Dunkel-* or *Besamungsschlag* (seeding felling), with the seed-bearers almost touching each other; (2) *Lichtschlag* (secondary felling), the canopy being opened to 15–20 paces between crowns, when regeneration is more or less complete, and 10–16 inches high; (3) *Abtriebsschlag* (final felling), the removal of the remaining seed-bearers when the young crop is 2–4 feet high. Cotta, in the first edition of his *Anleitung zum Waldbau*, recommended a procedure similar in the main to that of Hartig.

Hartig's influence made itself felt in Germany and in other parts of Central Europe, and his system was applied not only to broad-leaved but also to coniferous forests. It is still in force in many broad-leaved forests, but in the mixed spruce and silver fir forests it has been replaced to a large extent by other systems or combinations of systems, on the ground that the uniform system is impracticable in regions subject to storms.

In 1827 Lorentz[1] recommended the introduction of Hartig's *Dunkelschlagbetrieb* (uniform system) into France; it began to be introduced a few years later, but was not applied on any large scale in practice until the middle of the century, when it was introduced in the oak and beech forests in supersession of the old *tire et aire* system, as well as in certain spruce and silver fir forests of the Jura in supersession of the selection system. The famous oak forest of Bercé (Sarthe) was among the first of the French forests to be treated under this system, which was introduced there in 1846. Parade,[2] who had been a pupil of Cotta at Tharandt, was another strong supporter of the uniform system, which he termed *la méthode du réensemencement naturel et des éclaircies*, a somewhat unfortunate term, since neither natural seed regeneration nor thinnings are peculiar to the uniform system. At the time of its introduction into France from Germany it was referred to as *la méthode allemande*, and undoubtedly its introduction in modern times was due to Hartig's influence, although, as we have seen, something very similar to the uniform system has been known in France for centuries.

In the mild climate of the western half of France the uniform system gives strikingly good results, even with fixed self-contained periodic blocks; the rigidity of this arrangement, however, is recognized by many to be a drawback, particularly in the matter of allotment of age-classes to periods, for which reason there are now indications in some localities of a change to scattered periodic blocks. In the severer climate of north-eastern France the uniform system has proved far less successful for oak owing to the infrequency of seed-years, coupled, in some cases, with adverse soil conditions. It is practised in some of the silver fir or mixed spruce and silver fir forests of the Vosges and Jura, where it has been introduced in place of the selection system owing to the better quality of timber produced and to the advantages of concentrated working; here fixed periodic blocks are still the rule in some forests, although in others they have been abandoned in favour of floating periodic blocks, in order to secure that elasticity which is necessary in regions where damage by storms is prevalent. Far from abandoning the uniform system in these forests, however, the present tendency is to convert from the selection to the uniform system.

In Germany the uniform system is applied frequently to broad-leaved species and particularly to beech, in some cases to Scots pine,

[1] Bernard Lorentz, 1775–1865, Director of the Forest School, Nancy, 1824–30.

[2] A. L. F. Parade-Soubeirol, 1802–64, Director of the Forest School, Nancy, 1838–64.

and more rarely to spruce and silver fir. In some cases fixed but scattered periodic blocks are adopted, but more frequently the areas for regeneration are selected for a limited period ahead. Germany can show many fine examples of beech crops raised under this system, some, as in the Spessart, dating back to the earlier years of its introduction in Hartig's time.

In India the uniform system was first applied to the Himalayan forests of *Pinus longifolia* in 1895, and wherever conditions are favourable it has proved a complete success (see p. 56). India has little to fear from wind damage, and since this factor does not require to be taken into consideration, the uniform system has much to commend it owing to its simplicity. It is now being applied successfully, with suitable modifications, to other Himalayan conifers, as well as to the sal and other dipterocarps (see pp. 57–9).

The success with which regeneration under the uniform system has been obtained in the tropical rain forests of the Malay Peninsula (p. 58) indicates that with modifications to suit local conditions this system may yet become one of the standard systems of working and regenerating certain types of tropical forest. In many parts of the tropics the chief drawbacks to its adoption are the lack of markets for inferior species and the necessity for intensive and costly weeding in the interests of the young crop: under such conditions clear-cutting followed by artificial regeneration with the aid of shifting cultivation has generally proved more successful and less costly.

In Great Britain the chief drawbacks to the general adoption of the uniform system are the prevalence of rabbits, which prevent regeneration, and the excessive weed-growth so often present owing to the open condition of the woods. In the sandy and gravelly tracts of Surrey, Speyside, and elsewhere natural regeneration of Scots pine by uniform fellings has been obtained with complete success, while ash and sycamore often establish themselves in abundance where sufficient light is admitted, owing to the capacity of the young plants for penetrating a heavy growth of weeds. In these cases, however, the work of regeneration requires to become more systematized. The uniform system is being introduced in the Parmoor beech woods in the Chilterns, under a scheme prepared by the Oxford School of Forestry, and the experiment should give interesting results. In the Forest of Dean oak has been regenerated with success in enclosed areas. The best example of completed regeneration is to be seen in Blakeney Hill Wood North, where following an abundant oak mast-year in 1899 an area of about 500 acres was enclosed. Oak regeneration appeared in quantity, and

the seed-bearers were gradually removed, while gaps were planted up with beech. The result is an excellent uniform crop of oak and beech, 376 acres in extent, equal to anything to be seen on the continent of Europe.

10. INTRODUCTION OF THE UNIFORM SYSTEM IN UNEVEN-AGED FOREST

The introduction of the uniform system in uneven-aged or irregular high forest has been in operation since the middle of last century in certain coniferous forests of the French Jura which were formerly worked under the selection system. Conversion from irregular to even-aged high forest has also received much attention in India, where there has been great progress in silvicultural developments during the present century. The advantages of concentrated working and regeneration, as compared with fellings scattered far and wide over tracts of irregular forest, are so great that the future is likely to see a great development of concentrated systems of regeneration, based on the principles of the uniform system, in tropical, subtropical, and temperate regions.

In converting from irregular to uniform high forest, the fellings recognized are generally of two kinds, (1) regeneration fellings in areas allotted for regeneration for the time being, and (2) selection and improvement fellings, including thinnings, over the remainder of the area. Regeneration fellings can seldom be carried out with the precision characteristic of the uniform system itself. In many cases they consist of freeing regeneration which is already present (see under 'sal', p. 58), while supplementary artificial regeneration may also be necessary. The resulting young crops are often somewhat irregular, but the irregularity tends to disappear in time.

The selection and improvement fellings are intended to utilize mature timber and at the same time to remove defective or otherwise undesirable stems interfering with more promising members of the crop. These fellings pass regularly over those portions of the area which are not under regeneration, under a definite felling cycle as in the selection system (p. 110). Sometimes, however, crops containing much young growth are definitely allotted to the later periods of the rotation, and here the fellings consist of freeing the young growth from overhead cover, after the manner of secondary fellings.

V

THE GROUP SYSTEM

1. TERMINOLOGY

The term *group system* may be applied to what is generally known as Gayer's or the Bavarian *Femelschlag*, with a comparatively short regeneration period, and not the Swiss or Baden *Femelschlag*, which will be dealt with in the next chapter under the title *irregular shelter-wood system*.

The French equivalent is *méthode d'exploitation* (or *de régénération*) *par groupes*; the term *coupes par trouées* is also employed.

The following German terms may be mentioned:

Femelschlagbetrieb; applied originally to Hartig's uniform system, but now more commonly to the group system or the irregular shelter-wood system; it would apply most appropriately to the last-named.[1]

Gayers Femelschlag, *Bayrischer Femelschlag*, *Blendergrossschlag* or *Blenderschlagbetrieb*; terms used by Wagner to denote group or irregular fellings extending over whole compartments or other areas of some size, producing the *Blenderschlagform*, as opposed to the *Blenderstreifenschlag*, in which fellings are limited to part of the area and continued in a definite direction, or the *Blendersaumschlag*, in which they advance in narrow strips.

Kurzfristiger Blenderschlag is another term used by Wagner to denote the typical short-period group system of Bavaria.

Kesselhieb, *Löcherhieb* (gap felling).

Gruppenschirmschlag; this is perhaps the most distinctive and logical term to adopt.

Schirmschlagbetrieb; sometimes used to denote the short-period group system, but should be used more appropriately to denote the uniform system.

Ringförmiger Dunkelschlag, *Gayers Gruppenschlag* (Mayr).

Horst- und gruppenweise Verjüngung; a term which Gayer (*Der gemischte Wald*, 1886) wished to use in supersession of the term *Femelschlagverjüngung* which he originally applied to it.

[1] *Femeln* denotes to cut irregularly and *Schlag* denotes a definite felling area as distinct from scattered fellings all over the forest; hence *Femelschlag* implies irregular fellings over definite coupes.

Gruppen- und horstweise Schirmbesamung; Gayer includes under this both group (*Femelschlagform*) and selection (*Femelform*) fellings.

Lochkahlschläge or Ramann's *Lochkahlschläge* are small clear-cut gaps regenerated artificially.

2. GENERAL DESCRIPTION

Regeneration Fellings. The group system, like the uniform system, produces crops which are of the even-aged type by the time the pole stage is reached. During the thinning stages the treatment of the crops under both systems is identical, and it is not until the regeneration stage is reached that the two systems differ. Whereas under the uniform system the canopy is opened out evenly all over the compartment or other unit of regeneration, under the group system the first step is to go over the compartment and search for any promising groups of advance growth which may have appeared in gaps caused by wind, snow, or other agencies. If these groups of advance growth require freeing, the gaps are widened by felling trees round their edges (Ger. *Umsäumungshieb*), while at the same time, or as soon as a seed-year occurs, a seeding felling is made in the form of a ring round each gap (Ger. *Rändelhieb*). If there are not sufficient natural gaps over the compartment, further gaps are created artificially by felling trees in small groups. In this way numerous gaps are distributed over the regeneration area, which may be a whole compartment, or more commonly, only a portion of a compartment at a time. In the spruce and silver fir forests of Bavaria, when the initial gaps are made the general rule is to fell the largest trees, leaving the moderate-sized trees to act as seed-bearers and to put on increment; these moderate-sized trees are found to be better seed-bearers than the larger ones. As soon as regeneration has appeared in the artificially created gaps, a seeding felling is made round each gap as before. Regeneration thus spreads centrifugally round each gap; secondary and final fellings in turn follow the seeding fellings, while new seeding fellings continue outwards into the unopened old crop in ever-widening circles. The groups of regeneration thus become larger and larger and eventually meet, when the last remaining mother trees separating the various groups are removed, and only the regenerated young crop remains. The process of regeneration is shown in Figs. 27 to 31. Regeneration is sometimes aided by the removal of raw humus in and around the gaps. After the final felling blanks, if any, are planted up.

In freeing groups of advance growth at the beginning of the

regeneration fellings, it is necessary to concentrate on advance growth which is not seriously suppressed, and to remove any that has had its vigour destroyed by suppression. Some shade-bearers, notably silver fir, have the capacity for recovering after moderate suppression, but spruce and the more light-demanding species such

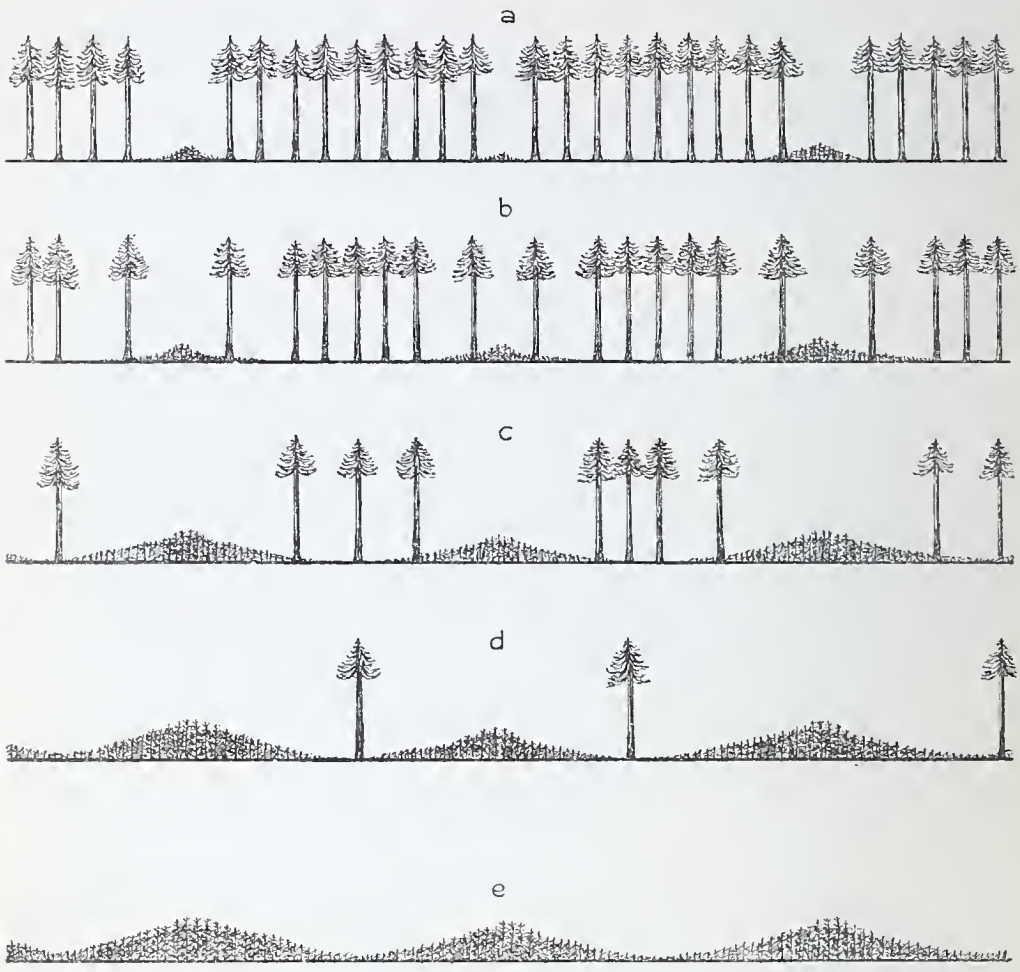

FIG. 27. Group system, showing successive stages of regeneration. *a*, initial gaps, with groups of advance growth; *b*, *c*, *d*, successive stages of enlargement of groups; *e*, regenerated young crop, showing wavy outline.

as Scots pine and larch do not recover satisfactorily if their vitality has been seriously impaired.

Formation of Gaps and Regulation of Mixtures. The initial gaps produced by wind or other natural causes vary in extent. If their size or condition is such as to render natural regeneration uncertain, they should be regenerated artificially without delay owing to the danger of soil deterioration or an influx of weeds. There is no

FIG. 28. Group system in forest of spruce and silver fir. Early stage in regeneration. Ground in foreground covered with spruce seedlings 5 years old and some silver fir. Group 14 years old behind. Older group opened out in left background. N. Kelheim, Bavaria.

FIG. 29. Group system in forest of spruce and silver fir with some beech, Scots pine, and larch. Group of spruce 14 years old; older beech group on right. N. Kelheim, Bavaria.

fixed rule regarding the size of artificially created gaps, though as a general principle this varies with the species. In the case of sensitive shade-bearers like beech or silver fir the canopy is only just broken, and the subsequent enlargement of the gaps is gradual; hence in order to regenerate a compartment in a reasonable time, there should be numerous gaps at no great distance from each other. In the case of spruce, gaps are commonly made about 20 to 25 yards in diameter or more. If the group system is applied to strong light-demanders, larger gaps would be necessary. Where there are two or more species present, the mixture can be regulated effectively by attention to the initial size and subsequent enlargement of the gaps. In those parts of Central Europe where the group system is most commonly practised, the forests consist as a rule of a mixture of spruce, silver fir, and beech, with or without Scots pine and larch. The size of the initial gaps and the manner of their subsequent enlargement depend chiefly on whether shade-bearers or light-demanders are to be favoured. Where spruce tends to become dominant, and special measures are necessary to favour silver fir or beech, initial gaps of small size are made round seed-bearers of these latter species, only one or two, or at most a few, trees being removed, so that the canopy is only just broken. Where spruce is to be favoured, larger gaps are made. Where one species tends to regenerate vigorously and to become dominant, it is sometimes customary to pull up seedlings of that species in the gaps where they threaten seedlings of other species; for instance, in regions where spruce is at its optimum and tends to become dominant—as in the Böhmerwald in S. Bohemia—this practice is sometimes necessary in order to maintain an admixture of silver fir and beech. Where there are strong light-demanders in the crop, such as Scots pine or larch, scattered seed-bearers of these species are left standing for a time over the young crop after the regeneration of other species is completed, in order to seed up blanks. Artificial regeneration may play an important part in the regulation of mixtures. Where the proportion of beech is insufficient, a procedure commonly followed is to introduce this species artificially in groups in advance of the regeneration fellings, after creating small gaps in the canopy. This practice is now fairly general in the pure spruce crops created artificially in Central Europe last century, crops which have suffered much from wind, snow, insect attacks, and soil deterioration. On patches of good soil groups of oak, ash, or maple are sometimes introduced artificially in this way. In this case gaps of some considerable size are created, particularly in the case of oak, which is

introduced in groups large enough to form self-contained units to be left over for a second rotation.

In some of the broad-leaved forests of Great Britain the practice is to carry out gap fellings for the introduction artificially of groups of conifers such as Douglas fir, *Thuja plicata* and other species, the chief object being to secure protection from gales or cold winds. The gaps are subsequently enlarged and further planted up until the whole area is regenerated. Round the edges of the gaps it is considered preferable to plant beech, which suffers less from suppression than other species and forms a useful mixture.

Protective Measures. In order to guard against damage by wind, a frequent modification of the procedure just described is to begin regeneration fellings in the eastern portion of the compartment and to continue them subsequently in a westerly direction, so that the unopened wood is retained as long as possible on the westerly or dangerous side of the group fellings. For this purpose it is usual to divide the compartment into say three parts, the eastern, central, and western; regeneration fellings are begun first in the eastern, later in the central, and last in the western part. In this case it is usual to make the gaps in close proximity to each other in order to hasten the completion of regeneration in each portion, otherwise the time taken to regenerate the compartment would be unduly long.

In places where the soil is liable to desiccation when exposed to the sun, a procedure adopted in recent years in parts of Bohemia is to enlarge the gaps successively on the south side only; this provides side shade from the sun on the southern edge of the gap where the seedlings are youngest and therefore in their most critical stage. This procedure is more effective than the carrying out of group fellings in the usual way progressively from N. to S., as is sometimes done. On hill-sides it is usual to begin regeneration at the top of a slope and to continue it by degrees in a downhill direction in order to minimize the damage done by sliding timber through well-established groups of regeneration. In order to give effect to these protective measures, a combination of the strip and the group systems has been evolved (see p. 101). Damage to young growth can be avoided to some extent by felling when there is snow on the ground and by directing the fall of the trees away from the groups of regeneration.

Periods and Periodic Blocks. Under the Bavarian group system the maximum duration of the period is somewhat similar to that of the uniform system, but the minimum duration is longer; in actual

FIG. 30. Group system in forest of spruce, silver fir, and beech. Enlarged gap, showing wavy outline of regenerated groups. Böhmerwald, S. Bohemia.

FIG. 31. Group system in forest of spruce, silver fir, beech, Scots pine, and larch. Regeneration nearly completed; wavy outline of young crop noticeable. Riedenburg forest, Bavaria.

practice periods of 20 to 30 years are the general rule in forests where spruce is the principal species, although periods up to 40 years are sometimes adopted; frequently the period is not definitely fixed but only approximately indicated. Gayer recognized periods varying from 15 to 40 years. A long regeneration period is usually objected to for spruce on the ground that damage caused during felling and extraction produces rot in the young stems, which is not the case with silver fir. In Europe the group system is generally practised in regions subject to storms and snow-damage, and hence floating periodic blocks are the rule; fixed periodic blocks would not be suitable under these conditions.

Form of Crop produced. The young crop produced by the Bavarian group system is the result of a succession of seed-years and is thus somewhat uneven-aged, with a wavy surface due to the presence of numerous thickets of different ages (see Figs. 27 *e*, 30, 31). If regeneration proceeds slowly and the gaps are widened gradually, the uneven-aged condition is more pronounced than where regeneration proceeds quickly and the gaps are widened rapidly; in the latter case the form of the young crop differs little from that obtained under the uniform system. Where the periods are equal, the group system produces more uneven-aged crops than the uniform system, owing to the inclusion of advance growth, but even under the group system any unevenness generally disappears by the time the pole stage is reached, and this system may therefore be regarded as essentially an even-aged system.

Swedish Modification of the Group System. A modification of the group system is in operation in many of the coniferous forests of northern and central Sweden, the species being Scots pine and spruce with birch. Initial gaps are generally under 1 acre but may be up to 2 acres in extent. In parts of northern Sweden, where work is less intensive, even larger gaps are sometimes made. Subsequent enlargement of the gaps takes place as a rule at rather long intervals, the enlargement continuing until the whole area is worked over. In order to promote the development of the remaining trees until the time comes for their removal in group fellings, thinnings somewhat resembling selection fellings are sometimes carried out in the intervening portions of the area. In the gaps themselves all birch and other cover is removed, in order to leave the soil completely exposed; slash, however, is left on the ground, though usually owing to intensive utilization the accumulation is not great. If natural regeneration fails the gaps are restocked by sowing and planting.

3. ADVANTAGES AND DISADVANTAGES OF THE GROUP SYSTEM

Apart from the advantages and disadvantages of shelter-wood systems in general, the following apply more particularly to the group system:

ADVANTAGES: 1. In making use of advance growth a start of several years is obtained in the process of regeneration; this is a distinct advantage where seed-years are not frequent, or where regeneration is not always certain.

2. The young crop develops in a somewhat more natural way than in the case of the uniform system, and its uneven-aged condition up to the pole stage is considered to be a protection against both snowbreak and sliding snow on steep hill-sides.

3. The group system makes use to some extent of the advantages afforded to the young crop by side protection[1] combined with complete overhead light at an early stage; so long as the gap is small, this tends to secure protection against frost, cold winds, and the desiccating action of the sun (but see under Disadvantages, 1).

4. In the earlier stages of regeneration there is less risk of damage from wind than under the uniform system; during the later stages, however, as the remaining seed-bearers become more isolated the risk is enhanced.

5. Damage by felling is avoided during the earlier stages of regeneration by directing the fall of the trees away from the groups of young growth; this no longer holds good when the groups begin to join up.

6. Mixtures can be easily regulated or created by regenerating or introducing species in groups, the size of the gaps being varied to suit the light requirements and sensitiveness of the species in question.

DISADVANTAGES: 1. Although the soil in the gaps is protected from the sun by the side shade of the old wood during the early stages of regeneration, as the gaps are enlarged the sun beats down on their northerly edges; where the soil is of a dry type this may cause heavy mortality amongst young seedlings, particularly of shallow-rooted species like spruce, and may thus seriously affect regeneration on those portions of the gap which are exposed to the sun. This risk may be counteracted to some extent by enlarging the gaps in a southerly direction only.

2. Serious damage by wind is liable to occur as the gaps become enlarged and the seed-bearers become isolated.

[1] The advantages of side protection are discussed on pp. 89 to 91.

3. On steep hill-sides much damage may be caused by the sliding of timber through groups of saplings during extraction.

4. Control is difficult, except where conditions render intensive working possible, owing to the irregular diffusion of large numbers of small centres of regeneration, each of which has to be searched for and located at frequent intervals during the course of regeneration.

5. Difficulty is sometimes experienced in opening out the gaps rapidly enough to keep pace with yield requirements while at the same time ensuring regeneration.

4. APPLICATION OF THE GROUP SYSTEM

The group system was advocated by Karl Gayer during the latter part of the nineteenth century, chiefly as a protest against the clear-cutting system, which had resulted in the conversion of natural irregular mixed woods into even-aged pure plantations of spruce. In his work, *Der Waldbau* (1st ed. 1878), he drew attention to the soil deterioration, the damage by snow and frost, and the depredations by insects and fungi, which had been brought about by the clear-cutting system. Consequently he strove as far as possible to have the woods brought into the more natural condition of mixed and uneven-aged stands. Although Gayer may be said to have systematized group fellings and brought them into special prominence, this form of regeneration is of fairly old standing; it is mentioned in the management rules of Bavaria in 1844, and was practised here and there before Gayer published his *Waldbau*.

Among those who supported Gayer were Ney and Burckhardt, while von Huber in Bavaria played a leading part in developing the system in practice. The group system, however, has not always found favour with the foresters of Germany, Borggreve in particular favouring the uniform system in preference to it. Even von Huber admits that it is not suitable for regions exposed to strong winds, nor for poor sandy or otherwise dry soils. It is essentially a system for fertile or at all events fresh soils, and for regions not exposed to severe storms, though so far as storm damage goes it is superior to the uniform system.

Nowadays the group system is seldom practised in its original form, having almost everywhere given place to the modification known as the strip and group system, which has the advantage of greater security against damage caused by wind and by the extraction of timber (see p. 101). Until recently the forests of Kelheim in Bavaria provided a classic example of the system, which gave good results under intensive management by a forest officer who

had been in charge of them for some thirty years, and whose intimate knowledge of local conditions was a strong factor in the success of the system. But even in the Kelheim forests the group system has recently been replaced by the strip and group system for the reasons just given.

Where intensive working is impracticable the group system is out of the question. It was introduced experimentally some years ago in the deodar forests of the Punjab Himalaya, but did not prove a success as it was impossible to give the necessary amount of close individual attention to the fellings.

As a means of obtaining a start with regeneration, the principle of gap fellings to free advance growth has much to commend it even where very intensive work is out of the question; it might be adopted with success in many types of forest, tropical, sub-tropical, and temperate. But further operations would generally have to consist of measures other than the frequent and gradual enlargement of the gaps as in the group system; they might, for instance, take the form of uniform fellings carried out simultaneously over the remainder of the area.

The group system in combination with the uniform system is not infrequently employed in the forests of Central Europe, particularly where the object is to introduce species artificially in mixture. As an example, conifers as well as oak and other hardwoods are introduced into beech forests in artificially created gaps, after which the remainder of the beech crop is opened out uniformly and regenerated naturally.

VI

THE IRREGULAR SHELTER-WOOD SYSTEM

1. TERMINOLOGY

This system, commonly known as the Swiss or Baden *Femelschlag*, may be defined as a system of successive regeneration fellings with a long and indefinite regeneration period, the chief object of which is to secure light increment for selected stems of the overwood and to produce young crops of a somewhat uneven-aged type for protective reasons.

The French equivalent is *méthode d'exploitation par coupes jardinatoires*.

The following German terms are employed: *Badischer Femelschlag*, *Schweizer Femelschlag*, *Langfristiger Blenderschlag* (Wagner), *Blendergrossschlag* or *Blenderschlagbetrieb* (see under Group System, p. 64).

The term 'Irregular Shelter-wood System' is proposed as a suitable English equivalent. The Swiss or Baden *Femelschlag* is sometimes referred to under the group system. Although in its initial stages it might in some respects be regarded as a form of the group or uniform system, it differs so radically from either of these two systems in its objects and application that it cannot be conveniently considered under either. Actually the system can best be regarded as a compromise between the uniform and group systems on the one hand and the selection system on the other.

2. GENERAL DESCRIPTION

Swiss Femelschlag. In Switzerland this system is applied to mixed forests of spruce, silver fir, and beech, sometimes with an admixture of other species such as Scots pine, larch, oak, ash, and maple. The general procedure is as follows:

1. A nominal rotation, generally of 100 years, is adopted, but this may be regarded merely as the average age of trees felled, the actual ages varying from, say, 80 to 120 years or more.

2. The regeneration period is an indefinite but long one, usually extending up to 50 years; the length of the period may vary considerably from place to place, even in the same compartment.

3. There are no periodic blocks; regeneration areas, which may be much scattered, are re-allotted every 10 years, and much latitude

is allowed, not only in regard to the selection of areas for felling each year but also in regard to the volume of material felled annually, provided that the total prescribed volume for the 10-year period is not exceeded.

4. Until regeneration begins the crop is subjected to light thinnings at frequent intervals, care being taken to keep it dense in order to produce clean boles, to protect the soil, and to prevent weed-growth.

5. Regeneration fellings begin with a slight opening of the canopy as soon as the trees are capable of bearing good seed, that is, when the crop averages about 60 to 70 years, while advantage is taken of any advance growth appearing in gaps caused by wind or snow; further successive regeneration fellings take place at frequent intervals, often with centrifugal enlargement of gaps as in the group system, the canopy being opened gradually where beech and silver fir regeneration predominates, and more rapidly where groups of spruce have to be freed; the final felling is made when the young crop is of any age up to about 50 years.

6. Owing to the gradual and somewhat irregular removal of the overwood, and the long regeneration period, an uneven-aged young crop is produced, but in time the irregularity becomes less apparent.

7. A certain number of the best-shaped stems of the overwood are retained for as long as the young crop will stand it, the object being to place these stems in the position of producing the maximum increment possible; in this way specially selected trees may remain until they are 130 or 140 years of age.

In practice the system varies in detail according to the composition of the crop. Where beech is present in sufficient quantity, the first light regeneration felling usually coincides with the occurrence of a beech mast-year, and results in the appearance of groups of beech regeneration. Silver fir follows soon after, and spruce later on, when there are sufficient gaps in the canopy. Last of all, light-demanders such as Scots pine and larch, if present, seed up blanks after the canopy has been well opened out, seed-bearers of these species being retained for this purpose. If necessary the conifers have to be assisted in the early stages by cutting away the beech regeneration in places. Where beech is not present in sufficient quantity, it is introduced artificially in groups, either in gaps caused by wind or snow or under a slightly opened canopy. Artificial regeneration of other species is carried out where necessary, light-demanders being employed to fill up gaps after the regeneration of shade-bearers has been completed. In some localities beech and

silver fir are regenerated first under the usual *Femelschlag* fellings, and spruce and Scots pine are regenerated afterwards by strip fellings (see p. 102 and Fig. 54).

The irregularity of this system may be realized from the fact that

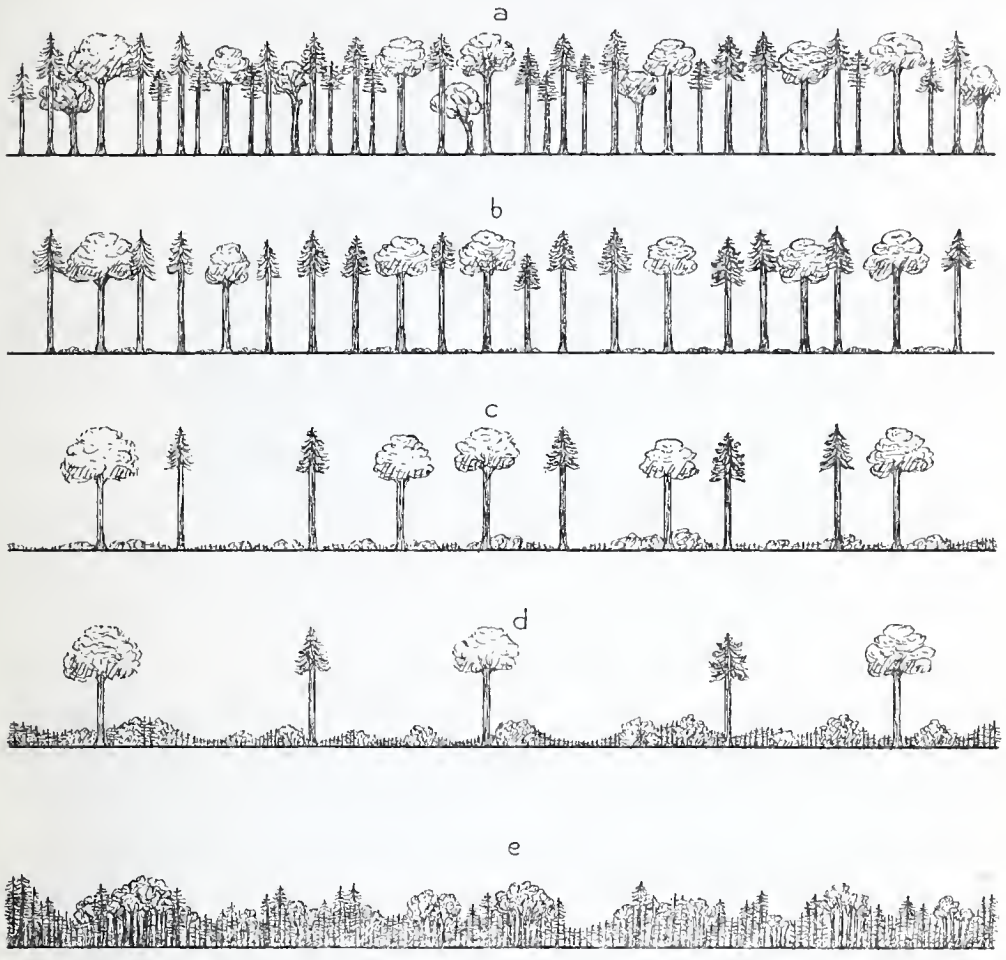

FIG. 32. Swiss *Femelschlag*, showing successive stages of regeneration in mixed forest of spruce, silver fir, and beech. *a*, mixed crop 40–80 years old (average 60 years), ready for regeneration to begin ; *b*, beech regeneration appearing as the result of a seeding felling ; *c*, regeneration of beech and silver fir establishing itself, and spruce appearing in gaps ; *d*, young crop with selected trees of the old wood retained for increment purposes ; *e*, young crop up to 50 years of age, after the final felling, showing irregular appearance.

one part of a compartment may be under regeneration while the remainder is not, while again some portions of a crop may be under thinnings while other portions may be still in the seedling or sapling stage with a considerable amount of overwood standing over the young crop.

Successive stages of regeneration are shown in Figs. 32 to 35.

Baden Femelschlag. The general principles of the Baden *Femelschlag* are similar to those of the Swiss *Femelschlag*. It is applied mainly to spruce and silver fir forests, in which as a rule the rotation is nominally 120 years but actually varies greatly, vigorous trees being left to grow and weakly or cankerous stems being cut out early. The regeneration period varies generally from 40 to 60 years, the longer period being adopted where silver fir predominates. Where the period is a long one the young crop has a very uneven-aged appearance (see Fig. 36). In this system great importance is attached to the production of storm-firm trees, while light increment in the best stems is considered to be more important than special measures to secure regeneration. For this reason there are no drastic seeding fellings; efforts are concentrated rather, during the thinning stages, on the individual development of the best stems with the object of securing vigorous seed-bearers with good crowns and root-systems, trees which when opened out will resist storms and put on rapid light increment. When such trees are obtained, natural regeneration follows as a rule without difficulty.

Regeneration fellings are carried out gradually and cautiously; in order to reduce damage to the young crop to a minimum they begin as a rule at the top of a slope and proceed in a downhill direction. The fellings take the form of freeing groups of advance growth rather than creating gaps deliberately, since the gradual opening of the canopy by the removal of defective stems generally results in the appearance of advance growth, while in addition there are often natural gaps caused by snow and wind. In some cases the removal of the overwood is completed by strip fellings, as in the case of the Swiss *Femelschlag*.

3. ADVANTAGES AND DISADVANTAGES OF THE IRREGULAR SHELTER-WOOD SYSTEM

The chief advantages and disadvantages of the irregular shelter-wood system are as follows:

ADVANTAGES: 1. The long period and the cautious opening of the canopy tend to prevent soil exposure and weed-growth, and to allow regeneration to appear with tolerable certainty.

2. The development of individual stems and the production of an uneven-aged type of crop are protective measures against wind and snow damage.

3. Enhanced increment is secured on the best and most valuable stems.

4. Time is saved in obtaining established regeneration, the young

FIG. 33. Irregular shelter-wood system (Swiss *Femelschlag*). Spruce, silver fir, and beech. Early stage in regeneration; beech and silver fir beginning to appear in groups. Forest of Bienne, Switzerland.

FIG. 34. The same. Later stage in development of shade-bearing group.

FIG. 35. Irregular shelter-wood system (Swiss *Femelschlag*). Regeneration well advanced; beech trees retained to put on increment. Forest of Bienne, Switzerland.

FIG. 36. Irregular shelter-wood system (Baden *Femelschlag*). Spruce and silver fir. Uneven-aged crop produced by long regeneration period; overwood not yet all removed. Herrenwies, Baden Black Forest.

crop being anything up to 50 or 60 years old by the end of the rotation.

5. The system is an elastic one, and gives a free hand to the manager (but see under Disadvantages, 5).

Disadvantages: 1. The system favours shade-bearers against light-demanders; in the Black Forest there are instances of mixed crops having been converted to pure silver fir by this system.

2. The young crop, kept for many years under cover of the overwood, does not develop so rapidly as it would if completely freed; the advantage of enhanced increment in the overwood, therefore, is discounted to some extent by retarded increment in the young crop.

3. Much damage may be caused during the felling of trees over the young crop and the extraction of timber through thickets of all ages and even groups of poles; this is particularly the case on steep slopes where logs get out of control. For this reason the lopping of branches is sometimes carried out prior to felling, thus adding to the cost of the work. In Switzerland damage is reduced to a minimum by carrying out all felling and extraction by means of skilled wood-cutters working directly under the Forest Department; felling and extraction by purchasers is never allowed in State forests.

4. The large area under regeneration at one time leads to diffusion of work and adds to the difficulty of supervision and control, and the scattered fellings add to the cost of working.

5. The elasticity and irregularity of working combined with the long regeneration period demand a good deal of skill on the part of the manager, and may result in serious mistakes, through lack of continuity, in the event of frequent changes of personnel.

6. Felling and logging amongst dense and often wet thickets is troublesome, and is unpopular with the woodmen.

7. The trees produced under this system are more branchy than those produced under the more even-aged systems.

4. APPLICATION OF THE IRREGULAR SHELTER-WOOD SYSTEM

This system is widely practised in the mixed spruce, silver fir, and beech forests of Switzerland, where, through Gayer's influence, it was introduced in the latter part of last century in supersession of the clear-cutting system, which had led to unsatisfactory results (see p. 20). In Baden, particularly in the Black Forest, it has been in operation for many years in spruce and silver fir forests, having to some extent superseded the selection system. In both regions the main ideas underlying its adoption were: (1) protection against

wind and snow, (2) adherence to natural methods, (3) maintenance of soil fertility, (4) enhanced production of timber. The first three of these advantages, at all events, have doubtless been secured, though at the expense of certain disadvantages enumerated in the previous section. It is significant that the success of this system has been greatest in districts where the same officer has been in charge for a long period of years. Close individual attention and intimate knowledge of local conditions are essential to its success, for which reason it is unsuitable for large areas where intensive working is impracticable, or where changes of personnel are frequent. It requires a good system of roads in order to counteract the effect of scattered work and to minimize damage on hill slopes by subdividing the areas under exploitation. It is adapted for the regeneration of mixed shade-bearers rather than of light-demanders.

In Switzerland this system is in some cases employed as a transition stage in converting from even-aged to selection forest, for which purpose it is well suited. In actual practice there are great variations in detail, and crops in all stages of transition may be met with. It would be equally suitable as a transition stage from selection to even-aged forest.

Where close supervision is not exercised, this system may result in grave damage. Instances have been observed in parts of the Black Forest where during temporary lack of supervision, owing to a change of personnel, extensive areas of thickets on hill-sides have been almost exterminated during the extraction of timber, resulting in large weed-covered blanks which necessitated costly artificial re-stocking. There is also a tendency, with changes of personnel, for work to become dislocated and responsibility to be evaded through insufficiently precise control over the progress of felling and regeneration. Areas may be seen where trees of the overwood have been left standing too long over the young crop, resulting in suppression of the latter or in scattered windfalls causing much damage to the young growth.

VII

STRIP SYSTEMS

1. GENERAL TERMINOLOGY AND CLASSIFICATION

Strip Systems comprise certain systems differing in detail but having one common characteristic, namely, that the coupes take the form of comparatively narrow strips, which have certain advantages, mainly of a protective character, over large coupes. The French term applied to a strip felling is *Coupe par bandes*. The following German terms may be mentioned:

Saumschlag, *Saumhieb* (strip felling); *Saumschlagbetrieb* (strip system). These terms denote very narrow strips, say up to half tree height or little more, cut along the edge of the old wood (*Saum*, Eng. seam, i.e. edge or border, hence *Absäumung*, meaning regeneration obtained on a narrow strip along the edge of the old wood).

Schmalschlag, the same as *Saumschlag*, but not so much used.

Streifenschlag denotes broader strips than *Saumschlag*.

For our purpose it will be convenient to classify the various forms of strip system as follows:

1. The shelter-wood strip system.
2. Wagner's *Blendersaumschlag*.
3. The strip and group system.
4. The progressive clear-strip system.
5. The alternate clear-strip system.

2. THE SHELTER-WOOD STRIP SYSTEM

General Description. The shelter-wood strip system (Ger. *Schirmsaumschlag*, *Saumweiser Dunkelschlag*) was evolved out of the uniform system for protective reasons. Under the uniform system the procedure of beginning regeneration fellings in the E. or NE. of a compartment and working towards the W. or SW., against the prevailing wind direction, has been in force in certain localities for over a century. This procedure required little adaptation to convert it into one of successive regeneration fellings—that is, seeding, secondary, and final fellings—carried out in narrow strips running more or less at right angles to, and advancing progressively against, the prevailing wind direction. Hence, when the main object is protection against the wind, the regeneration of a compartment

begins with a seeding felling of the uniform type carried out over a narrow strip along the eastern or north-eastern edge of the compartment. As soon as regeneration on this strip is sufficiently advanced, a secondary felling is made over it, and a seeding felling is carried out along a second strip adjacent to the first one and on its

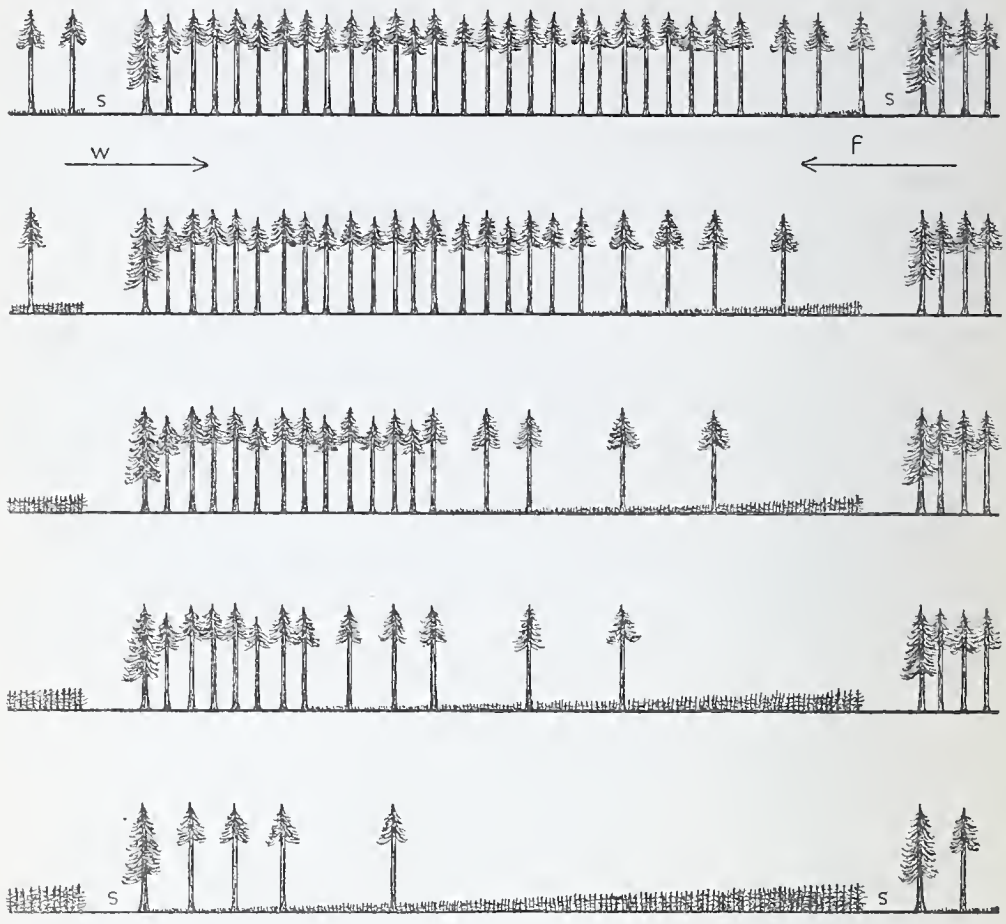

FIG. 37. Shelter-wood strip system, showing progress of fellings through a cutting section. *s*,*s*, severance cuttings ; *f*, felling direction ; *w*, wind direction.

windward side. When regeneration is sufficiently advanced on this second strip, it is subjected to secondary fellings and the first strip to further secondary or to final fellings, and a seeding felling is carried out along a third strip adjacent to the second one. In this way regeneration fellings advance progressively against the wind direction in a series of narrow strips. The progress of regeneration is represented diagrammatically in Fig. 37, while Figs. 38 and 39 show the appearance of strip fellings and regeneration.

In the shelter-wood strip system, as in the uniform system, the

FIG. 38. Shelter-wood strip system of Württemberg in forest of spruce, silver fir, and Scots pine. Strip felling on level ground proceeding from left to right (NE. to SW.) against the prevailing wind. Pfalzgrafenweiler, Black Forest. (*Note*. The logs seen in the picture are lying beside a road, and have not been felled into the young growth.)

FIG. 39. Shelter-wood strip system of Württemberg in forest of spruce and silver fir. Strip felling on hilly ground proceeding in a downhill direction and also against the prevailing wind. Regenerated area in foreground. Schönmünzach, Black Forest.

number and the frequency of regeneration fellings vary with species, locality, conditions for regeneration, and other factors; in practice the number of successive regeneration fellings is by no means constant over each strip, since regeneration may appear more readily in some places than in others, necessitating a more rapid opening of the canopy in the former case than in the latter. Thus the number of successive strips under regeneration at one time may vary, although theoretically there are generally three, in the seeding, secondary, and final stages respectively.

The strip in the seeding stage is generally well defined, but those in the later stages often merge into each other, and their limits are not so readily distinguishable. Even after the final felling is completed the regeneration of light-demanders may continue for a time on the cleared strip. As a rule regeneration proceeds more rapidly under the strip system than under the uniform system, owing partly to the effect of side light before the seeding felling is made, partly to the larger quantity of seed provided by the adjoining wood, and in some cases to the protective influence of the latter.

The regulation of mixtures is carried out on lines similar to those adopted for the uniform system. In mixed forests of spruce, silver fir, Scots pine, and beech, the shade-bearing silver fir and beech are regenerated first by a slight opening of the canopy, the spruce appears as the canopy is opened further, and Scots pine seed-bearers are retained for a time over the strips from which all the other species have been removed, in order to regenerate gaps. Sometimes the regeneration of shade-bearers is stimulated in advance of the regular strip fellings by opening the canopy slightly for some distance ahead of them, or even over the whole area to be regenerated, so that when the strip fellings are carried out the regeneration of the more light-demanding species may proceed rapidly.

Form of Strips. The breadth of the strips varies according to circumstances. In the Württemberg Black Forest, where this system is well exemplified, new strips about 20 to 30 yards in width, or occasionally more, are put under seeding fellings at one time, and the total width of the belt under regeneration, from the seeding to the final stage, averages about 75 yards, though the actual width varies greatly according to the progress of regeneration.

On level ground the strips, at all events in the earlier stages, are generally in the form of straight lines, and this is also the case on hill-slopes in so far as the configuration of the ground permits. As the strips advance they tend to become more irregular, owing to the fact that regeneration does not always establish itself evenly

throughout their length. The local configuration or the shape of the regeneration areas may require strips which are not straight lines. In order to present a longer front, and thus accelerate the regeneration of an area, the strips are sometimes given a wavy or serrate or step-like outline, which has the disadvantage of complicating the alignment of the strips and is not to be recommended if it can be avoided.

Alignment of Strips. The original idea underlying the adoption of the shelter-wood strip system was the necessity for working against the prevailing westerly wind, so that the newly exposed edges of mature woods should always be protected from it. Hence on fairly level ground the strips are laid out more or less at right angles to the wind direction, and advance in a westerly to south-westerly direction against it. The trees are always felled into the old wood, and the timber is dragged out through it and not through the young crop.

In hilly country there are two primary considerations in deciding on the arrangement of strips, (1) the local wind direction, since the trend of the valleys and the general configuration frequently divert the prevailing westerly winds or cause strong local winds, and (2) the question of avoiding damage to the young growth during the extraction of timber down the hill-sides. Requirements in these respects are met by first determining the local dangerous wind direction and then arranging the strips so that in the first place the wind may not strike against the exposed edges of the old woods, and in the second place timber may be extracted down the slopes to the nearest road without passing through any young crops.

In practice the strips are laid out either horizontally along the contours, or vertically up and down the slope, or at an inclination to the horizontal or vertical, according to the wind direction and other considerations. In the case of strips which are horizontal or slightly inclined to the horizontal, fellings begin at the top of the slope and advance in a downhill direction, so that timber descends through the old wood and not through the young crop (see Fig. 43). In the case of vertical strips or those moderately inclined to the vertical, the trees are felled into the old wood and the timber descends through it. Frequently horizontal and vertical strips are both found in the same locality, one or the other being adopted according to the wind direction; sometimes both are combined on the same slope, with the object of accelerating the regeneration of an area.

The necessity for affording protection against wind has led to

the preparation of special 'felling keys' as a guide to the alignment of strips and the felling direction on different aspects in hilly country. Fig. 40 shows such a felling key prepared in 1885 for the Neuessing forests, Bavaria.

In Central Europe one of the most dangerous local winds is that which sweeps over a plateau from the west and drops down the eastern slope flanking it. In the case of horizontal strips advancing

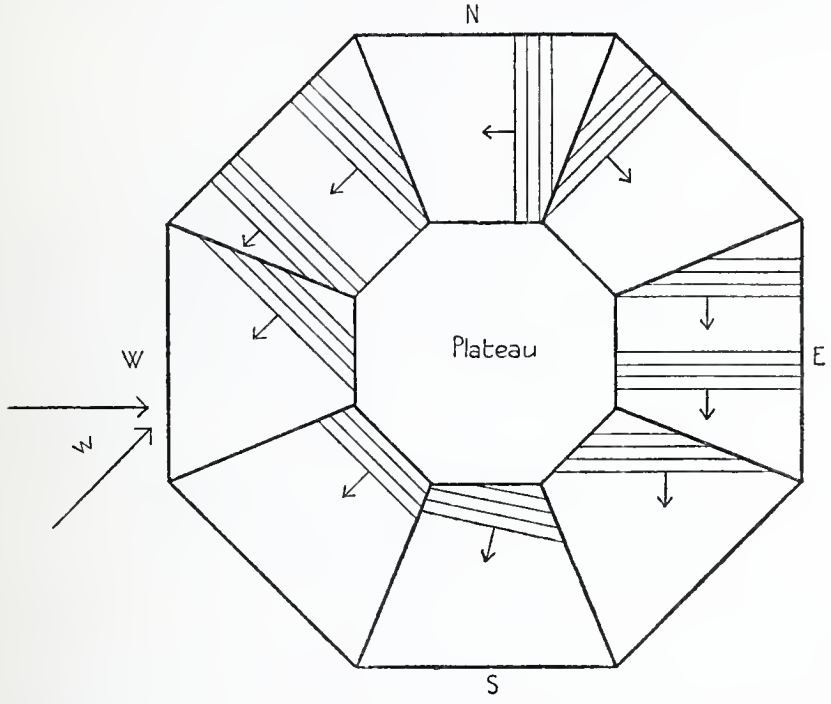

FIG. 40. Shelter-wood strip system. Bavarian felling key, showing arrangement of strips on slopes of different aspects. Small arrows show felling direction ; *w*, wind direction.

from the top of the slope downwards, such a wind would strike the exposed edge of the wood, and hence on slopes swept by a descending wind of this kind it is customary to adopt vertical strips. The arrangement shown in Fig. 41 is adopted on the southern slopes of certain mountains in Austria to guard against the west wind as well as a wind descending from the mountain tops. Here the fellings in the lower sections of the slope proceed in advance of those in the sections above them, so that there is always a sheltering wood immediately on the uphill side of the exposed strips.

Hitherto we have considered the arrangement of strip fellings with special reference to protection against prevailing winds, for which purpose a felling direction from E. to W. or from NE. to

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SW. is the rule in continental Europe. In recent years Dr. C. Wagner has demonstrated that wind is by no means the only factor to be reckoned with in the arrangement of strip fellings, and that there are other factors, and in particular the sun, which may exercise a profound influence on natural regeneration. He has shown that under certain conditions the adverse effect of the sun, in causing the desiccation of the soil and preventing regeneration, is so great that strip fellings ought to proceed not from E. to W. but from N. to S., in order that the strip under regeneration may receive the lateral

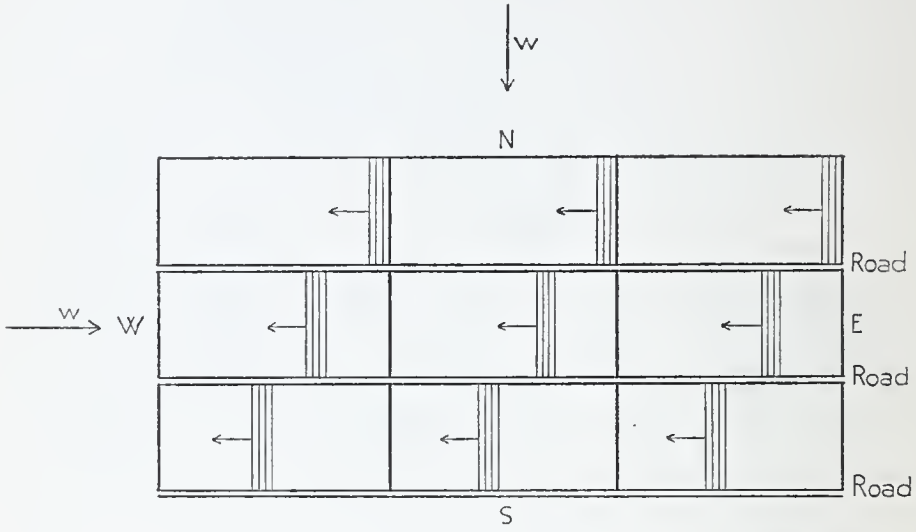

FIG. 41. Shelter-wood strip system. Arrangement of vertical strip fellings on a southern slope with the object of providing a safeguard against the west wind and also against a descending wind from the north. *w,w*, wind directions ; small arrows show felling direction.

shade from the sun which is afforded by the old wood to the south of it. This question will be discussed in detail in the next section.

Cutting Sections. The rate at which strip fellings advance through an area depends mainly on the rapidity with which regeneration appears and establishes itself, and therefore varies greatly under different conditions. In the spruce and silver fir forests of Central Europe the average rate of advance ordinarily varies from under 2 yards to about 10 yards a year. Where the rate averages 2 yards a year it would take a whole rotation of 120 years to regenerate a compartment of 240 yards in length, and the crop would consist of a series of parallel even-aged strips from 1 to 120 years old arranged in regular succession from one end of the compartment to the other. This is a perfectly legitimate arrangement, and the idea is actually followed out in Wagner's *Blendersaumschlag*. But in the typical

form of shelter-wood strip system which was evolved out of the uniform system, even-aged crops and comparatively short regeneration periods—sometimes as short as 20 years—are aimed at. Hence it is necessary to divide the area to be regenerated into a number of

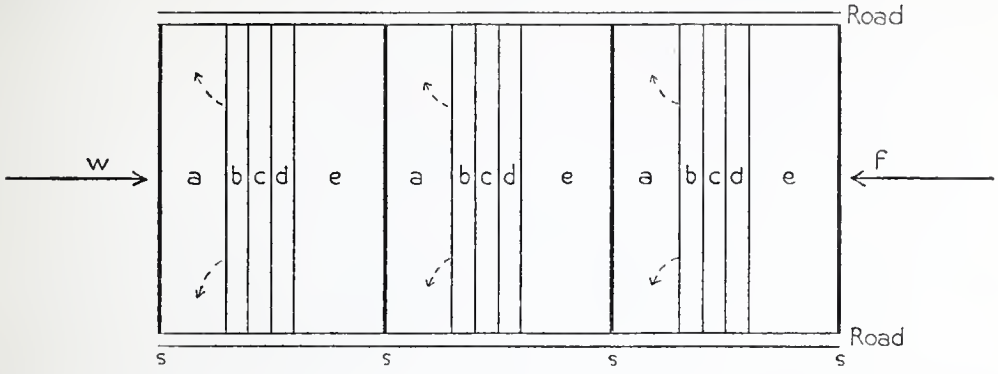

FIG. 42. Shelter-wood strip system on level ground, showing three cutting sections with felling direction against the wind. *a,a,* old wood ; *b,b,* seeding fellings ; *c,c,* secondary fellings ; *d,d,* final fellings ; *e,e,* young regenerated crops ; *s,s,* severance cuttings ; *f,* felling direction ; *w,* wind direction. Dotted arrows show direction of timber extraction.

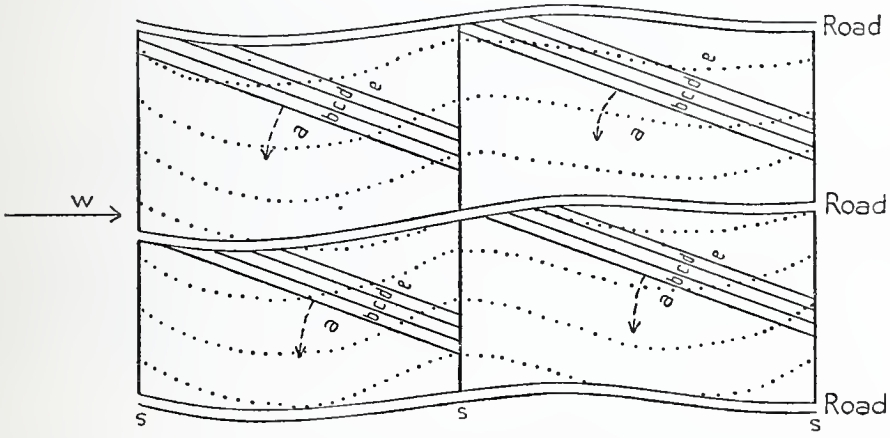

FIG. 43. Shelter-wood strip system on a hill-side, showing felling direction partly against the wind and partly downhill. Letters as in Fig. 42. Dotted lines represent contours ; dotted arrows show direction of timber extraction.

cutting sections (cf. p. 7), each of such a length that the strip fellings will advance from one end of it to the other in the number of years representing the regeneration period. For this purpose it is necessary to fix the regeneration period, if only approximately, and to estimate the mean annual rate of advance of the strip fellings; the length of the cutting section will then be the product of the two. Thus if the regeneration period is taken to be 25 years and the

average rate of advance is estimated at 5 yards, the length of the cutting section will be 125 yards; if the area to be regenerated is 500 yards in length, therefore, it will be necessary to divide it into four cutting sections. The shorter the cutting sections, and the more rapid the advance of the strip fellings, the more even-aged will the young crop be. A slow rate of advance produces a steeper slope in the profile of the young crop than a rapid rate of advance.

Broad cutting sections, that is, long strips, are an advantage from more than one point of view. In the first place work is more concentrated, and therefore less complicated and costly, than it is where felling and extraction are scattered over numerous short strips. In the second place a broad cutting section with no great length can be regenerated in a shorter time than an equal area of considerable length with no great breadth; regeneration therefore need not be unduly hurried, a matter of importance if much supplementary artificial regeneration is to be avoided.

The formation of cutting sections on level and on hilly ground is illustrated in Figs. 42 and 43. In forming cutting sections, the risk of exposing unprotected woods to the prevailing wind should be avoided. For this reason roads and other permanent lines should be utilized as far as possible to separate the cutting sections. Where it is necessary to divide woods into two or more cutting sections, severance cuttings (see p. 8) should be made if the wood is still young enough for low-branching border trees to develop.

In the formation of cutting sections on hill-sides, horizontal or slightly inclined strips should be avoided unless there is a good system of contour roads at fairly frequent intervals, as shown in Fig. 43. Where there is a long slope without such roads, timber from the upper sections will have to pass through young crops in the lower ones. On such ground vertical strips are preferable if there is no suitable road system.

Advantages and Disadvantages of System. The following are the chief advantages and disadvantages of the shelter-wood strip system:

Advantages: 1. It provides side protection in a definite direction; in the original system as just described the protection is against the west wind, while in Wagner's *Blendersaumschlag*—a modification described in the next section, in which strip fellings proceed from N. to S.—the protection is against the sun; side protection is now generally recognized as being more effective than overhead cover in localities subject to frost and drought, and in this respect the advantage possessed by felling in strips is apparent.

2. Side light is utilized to the utmost, and complete overhead light is available at an early stage, since even sensitive species may be uncovered rapidly owing to the side protection afforded by the old wood; this admission of light stimulates the development of seedlings and is favourable to the regeneration of light-demanding species.

3. Damage to the young crop during felling and extraction is minimized owing to the fact that trees are felled into the old wood and timber is extracted through it.

4. Cultural and tending operations can be supervised easily, and the progress of regeneration can be followed without difficulty.

5. The progress of regeneration can be controlled readily in relation to the yield; where it tends to proceed too rapidly it may be retarded by decreasing the number of cutting sections or narrowing the strips, or it may be accelerated if desired by increasing the number of cutting sections or broadening the strips.

Disadvantages: 1. The fellings are scattered in many different places.

2. Storms occasionally come from unforeseen directions and may do much damage.

In practice the former objection scarcely holds, since fellings along the strips are fairly concentrated and the strips themselves are easily located.

Application of System. The shelter-wood strip system, as we have seen, was developed from the uniform system. Under the latter system the idea of beginning regeneration fellings in the E. or NE., and proceeding towards the W. or SW. against the prevailing wind, certainly existed in Germany in the beginning of the nineteenth century if not earlier. Cotta (*Anweisung zum Waldbau*, 1817), in describing the uniform system, says that where there is danger from storms the fellings should proceed from NE. to SW., particularly in the case of spruce woods. Even the division into cutting sections appears to have been recognized a century ago: Hundeshagen (1828), referring to spruce shelter-wood strip fellings proceeding from NE. to SW., states that in order to obtain the yield from such narrow coupes, many separate coupes are necessary. Subsequent German writers of the nineteenth century make frequent reference to strip fellings and to the employment of several lines of attack, meaning the division of the area into cutting sections.

In more recent times the shelter-wood strip system has been extended considerably, and in Württemberg in particular it has been greatly developed, having superseded the uniform system with a

short regeneration period; on this account it is sometimes termed the Württemberg strip system. Where reasonably short cuttings sections have been formed it has succeeded well, but the tendency has frequently been to form too large cutting sections, with the consequence that natural regeneration has been unable to keep pace with yield requirements, and much supplementary planting has been necessary. Until recently the felling direction in Württemberg has always been against the prevailing wind, that is, from E. to W. or from NE. to SW., but under Wagner's influence this is being abandoned in some places for the N.–S. direction. There is also a tendency to make more use of advance growth than was the case formerly, and to adopt the strip and group system described later.

The shelter-wood strip system in one form or another—including Wagner's *Blendersaumschlag* and the strip and group system—is much in favour at the present day, and the tendency in Central Europe is to extend its use in place of other systems. In France it has been tried to a very limited extent in the spruce and silver fir forests of the Jura.

3. WAGNER'S *BLENDERSAUMSCHLAG*

Definition and Terminology. Wagner's *Blendersaumschlag* is a form of strip system in which the fellings are carried out in narrow shelter-wood strips extending in an E.–W. direction and advancing from N. to S., the object being to afford side protection against the sun to the seedlings on the strip under regeneration. The system was first elaborated in the forests of Count Pückler-Limburg at Gaildorf in Württemberg by Dr. Wagner,[1] who was in charge of these forests from 1898 to 1903. In the latter year he was succeeded by Forstmeister Rau, who has been largely responsible for carrying out Wagner's ideas in practice. The *Blendersaumschlag* system was actually introduced in Gaildorf in 1902.

The term *Blendersaumschlag* has given rise to a great deal of misunderstanding as to the real nature of the system and the method of executing the fellings. This is probably due to the use of the word *Blender* (i.e. *Plenter*), which might be taken to imply selection fellings producing an uneven-aged type of crop (cf. under Selection System, p. 109). Consequently the *Blendersaumschlag* has been

[1] Dr. Christof Wagner, Professor of Forestry in the University of Freiburg, formerly Director of Forests in Württemberg. Full details regarding this system and its underlying ideas will be found in Dr. Wagner's two books, *Die Grundlagen der räumlichen Ordnung im Walde*, 4th ed., 1923, and *Der Blendersaumschlag und sein System*, 2nd ed., 1915 (H. Laupp, Tübingen).

assumed to be a form of selection system in strips, producing uneven-aged crops, and has been rendered in English as 'Strip Selection System' or some other term of a similar kind. Actually the system as practised at Gaildorf is an even-aged one, in that it produces approximately even-aged crops over areas of appreciable extent, as will be apparent from the subsequent description of it. Wagner employs the term *Blender* to denote not fellings of the kind characteristic of the selection system, but fellings aiming at an uneven opening of the canopy (*Blenderhieb*) along the border strip; he does not insist on any one particular method of executing the fellings, but leaves this to be determined by local conditions. These somewhat elastic or selective shelter-wood fellings, which give rise to the term *Blender*, are of special importance in the regulation of mixtures. Since sporadic seed-bearers may be utilized in years of poor seeding, such fellings also facilitate regeneration.

Influence of lateral Shelter. Before going into the technique of Wagner's *Blendersaumschlag*, it is necessary to appreciate its great underlying idea, namely the outstanding importance of the sun as a factor adverse to the establishment of natural regeneration under certain conditions. Wagner evolved his system after an extensive series of observations and experiments at Gaildorf, in mixed forests consisting chiefly of spruce, silver fir, beech, and Scots pine. The species on which he concentrated his attention more particularly was the spruce, the regeneration of which gave most trouble.

Following the accepted procedure of beginning strip fellings along the eastern and north-eastern edges of a wood and advancing them progressively towards the W. and SW., he observed that although spruce seed germinated well, the seedlings, owing to their shallow root-system, died of drought during the dry weather usually prevalent in June. On the other hand it was always in places sheltered against the south that regeneration was found to establish itself in quantity, while nowhere was there better regeneration or a better mixture of all species than in certain small gaps, made by storms and otherwise, along the NW. edge of the old crop. Following up the evidence thus collected, further observations were made along the edges of woods in all directions of the compass, and the factors operating on the various edges were studied in connexion with shelter-wood strip fellings. For this purpose it is convenient to divide the whole strip under regeneration into two portions, the *inner strip*, comprising the portion opened out for regeneration, on which a part of the overwood still remains, and the *outer strip*, that on which all the overwood has been felled but which receives some

side protection from the trees standing on the inner strip: thus the inner strip receives overhead as well as side protection while the outer strip receives side protection only. The following, according to Wagner's observations, are the chief factors operating on the different edges of a wood, in their relation to natural regeneration·

Wind: a powerful desiccating agent if unaccompanied by rain, and in this condition inimical to regeneration. Dry winds are most prevalent from the east.

Rain is of two kinds: (1) more or less perpendicular rain which soaks the ground, and (2) light rain which is almost always brought by the west wind, falling in a slanting direction. This light rain does not as a rule drench the ground, but only wets the upper layers; it occurs chiefly in the dry seasons, spring and summer, and is of importance for shallow-rooted species. Ordinarily this rain is too light to pierce the canopy to any extent.

Dew is an important factor: it remains longest on the north edge of a wood and helps to prevent mortality among seedlings through desiccation.

Frost is a very harmful factor, and does most damage in places exposed to the morning sun.

Snow is a beneficial factor in (1) protecting seedlings from damage by deer, (2) keeping the ground cool and causing later sprouting and thus lessening the risk of damage by late frost, and (3) moistening the ground thoroughly. Snow, blown chiefly by the SW. winds, lies deepest on the lee of the N. and NE. edges; here it is not subject to alternate freezing and thawing as on the S. side, and hence on northerly edges there is less risk of damage by ice.

Sun is a most noxious agent, drying up the soil and causing high mortality among seedlings.

Now since agencies which bring moisture to the soil may be regarded as generally favourable to regeneration and those which have a desiccating effect on it are unfavourable, the following conclusions may be arrived at regarding the different points of the compass in their relation to regeneration by means of strip fellings.

E., SE., and S. These sides of a wood are altogether unfavourable. On the E. the morning sun penetrates even into the inner strip, and no light west rain gains admission to it; conditions are thus unfavourable both in the inner and in the outer strip. The night dew is at once dried up by the morning sun, while there is much danger from frost through the rapid thawing of frozen shoots.

S. to SW. Almost as unfavourable as the preceding, except that the action of the dry east wind and of the morning sun in its relation

to frost damage do not come into play: the SW. side benefits by the light west rain, it is true, but it also receives the full effect of the afternoon sun.

W. Rather more favourable. The midday sun does not penetrate to the inner strip, while the light west rain penetrates freely: the afternoon sun, however, is unfavourable.

NW. and N. The NW. is the most favourable side of all: here there is free admission of the light west rain into the outer and inner strips, complete protection from the midday sun and the dry east winds, and partial protection from the west wind. The beneficial influences of snow also come into full play. The N. is slightly less favourable than the NW., since the light west rain falls only on the outer strip; there is, however, protection from the morning as well as the afternoon sun, while some light rain beats in from the NW. On the NW. regeneration, especially of shade-bearers, appears even in the inner strip: on the N. it appears chiefly on the outer strip. Both on the N. and on the NW., conditions are particularly favourable for the formation of dew. The ground and the vegetation are not warmed by the sun, and hence the formation of dew commences with the exit of the damp air from the interior of the crop early in the evening and continues till the morning. The dew is thus heavier than on other aspects, while, being sheltered from the sun, it remains longer on the ground during the day.

NE. Sheltered from the midday sun but not from the morning sun, which dries up the night dew and adversely affects regeneration in frosty weather; does not receive the light west rain either on the inner or on the outer strip. This side of a wood has the advantage of shade from the sun all day except in the morning, but this is counterbalanced by dry easterly and north-easterly winds.

To summarize these conclusions, the NW. and N. sides of a wood, and particularly the former, are most favourable to regeneration, the NE. coming next: other sides are unfavourable, E. to S. being decidedly sterile. Wagner therefore decides that the ideal direction in which strip fellings should proceed is from NW. to SE., but where there is danger from wind it is necessary to alter the direction to one of N. to S.

In steep hilly country there are exceptions to the general rule. The winds bringing rain are as a rule diverted from their course and blow along the slopes. The effect of the sun is strengthened or weakened according to the angle at which it strikes the surface of the ground: thus on S., SE., and SW. slopes the sun exercises a much more adverse influence than on N., NE., and NW. slopes.

It should be remembered that Wagner's observations and conclusions have special reference to Gaildorf, where the forests are situated at elevations between 1,000 and 2,000 feet on Middle Permian marly sandstone; the normal rainfall is about 30 inches, and there are occasional periods of long drought in the spring which are particularly unfavourable to spruce seedlings with their shallow root-systems. Under such conditions protection from the desiccating action of the sun might well be expected to be an important condition for successful regeneration; in drier climates it would be an even more essential condition. Wagner's conclusions are by no means applicable to Gaildorf alone; they have been fully confirmed in many other regions where the desiccation of the soil is a factor to be reckoned with, and Wagner's strip system is now successfully applied in many parts of Central Europe.

Evidence of the value of side protection from the sun is by no means confined to Europe. Various observations made by the writer in the Himalayas have shown that on dry slopes natural regeneration of deodar (*Cedrus Deodara*) and spruce (*Picea Morinda*), and even of the drought-resisting *Pinus longifolia*, is greatly favoured by lateral protection from the sun.

On the other hand, even in the case of the European spruce, at the higher elevations with abundant rainfall and a cool climate, protection from the sun may be not only unnecessary but even harmful. Thus in certain parts of the Böhmerwald, in South Bohemia, where much moister conditions prevail than at Gaildorf, strip fellings from N. to S. have failed owing to excessive damp and rank weed-growth. In the forests of Kamenitz in South Bohemia, where *Blendersaumschlag* fellings from N. to S. are practised with success, it is found preferable in moist situations to carry out fellings from S. to N. In the forest of the Sihlwald in Switzerland, fellings advancing from S. to N. give results as good as those advancing from N. to S. In the forest of Eschenberg near Winterthur strip fellings advancing from S. to N. are considered preferable even to those advancing from N. to S., since warmth and abundance of side light are considered to be of more importance than protection against the sun. In northern latitudes, where there is a long and intensely cold winter and a short growing season, it is not improbable that fellings from S. to N. may be found most favourable to regeneration. Soil moisture has less effect on the regeneration of broad-leaved species than of conifers, for which reason, according to Bühler, some of the older writers make the proposal that fellings in broad-leaved woods should proceed from S. to N.

As regards Scots pine, Dr. Wiedemann, in an article[1] which summarizes the experience of other writers as well as the results of his own investigations in Saxony and in other parts of Germany, comes to the conclusion that side shade does not help the growth of the young plants but rather in many cases hinders it, sometimes permanently. In the cases which came under notice, the adverse effects of side shade extended in nearly every case to 3–8 metres and often to 15 metres from the old wood, the injury being greatest in fellings from N. to S. or from NE. to SW., that is, where the sun was kept off. On other exposures most of the harm was done by drip and root competition. The adverse effects of side shade from the sun were not very pronounced on dry ground with little grass, but in moister situations, especially on fertile grass-covered ground, many plants were found to die off in the first year, while many succumbed in the earlier years to needle-cast (*Lophodermium Pinastri*).

From the general point of view, therefore, the great value of Wagner's work lies not only in demonstrating the necessity, under certain conditions, for maintaining side protection against the sun, but even more in drawing attention to the importance of studying the various factors operating on different edges of a wood, with the view of determining if any of the edges are specially favourable to regeneration or the reverse, and arranging the felling direction accordingly. The principle of working to the compass, to which Wagner has drawn attention, is one which is likely to have far-reaching application not only in temperate but also in tropical countries.

Records show that the advantages of side protection from the sun, so well demonstrated by Wagner, were appreciated to some extent even in the early part of last century. Zötl, writing in 1831 with special reference to the Tyrol, says that coupes should be so arranged that the chief injurious factors, strong sun and wind, should be guarded against.

In the highlands of Swabia in Bavaria strip fellings from N. to S. were in operation before the middle of last century. This tract, lying at an elevation of some 1,600 to 2,000 feet above sea-level, has a mean rainfall varying from 25 to 30 inches, and the forests are situated for the most part on coarse-grained permeable sands, hard sandstones, quartzites, and crystalline rocks. In the working plan of Oberkammlach, 1843, narrow strip fellings advancing from N. to S. are prescribed for spruce, the object being to provide side shelter from the sun. In the working plan of Franken-

[1] *Zeitschrift für Forst- und Jagdwesen*, June 1926, p. 333.

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hofen-Sachsenried, 1844, the advantage of side protection from the sun is definitely stated in the following words (translation): 'In view of the unfavourable influence of the southern exposure on spruce and beech regeneration, through the prolonged heat of the sun . . . the fellings in future should proceed not from E. to W., but rather from NE. to SW. or NNE. to SSW., and where local conditions permit or demand it, even from N. to S., since experience hitherto has shown that by such a felling direction the young growth and the soil receive more protection and shelter owing to the presence of the adjacent stand, and natural regeneration is particularly successful.'

The procedure in force for some of the spruce forests of South Bavaria about the middle of last century was to make seeding fellings in long narrow strips advancing from NNE. to SSW. or from N. to S.; secondary fellings were carried out 4–6 years and final fellings 6–8 years after the seeding fellings.[1]

Basis of System. Wagner does not claim any rigid distinguishing features for his system save in two respects, (1) the form of the coupe, which should be a long narrow strip, and (2) the compass bearing of the coupe, that is, it should extend from E. to W. in order to secure the advantages of side protection from the sun. Even these two features are not strictly unalterable, and are subject to modification under special circumstances. All other conditions, such as the nature of the fellings, the interval between them, and the rate at which they advance, are freely alterable to suit individual cases.

In evolving this system, Wagner has been guided by certain considerations which he regards as of fundamental importance in respect of systems in general. Among these are (1) the desirability of securing mixed crops by means of natural regeneration, and avoiding pure crops and artificial regeneration, (2) the avoidance of extensive clearings, (3) the advantage of bringing trees up in even-aged form in relation to those immediately round them, in order to secure a good shape of bole and an even structure of timber, (4) a definite area separation of the age-classes, and the felling of trees away from young growth, with the object of avoiding damage, (5) the question of securing close supervision and easy control.

By adopting a system of strip fellings Wagner claims to have secured these advantages, and above all he regards the felling direction from N. to S. as the chief factor in securing natural regeneration of the desired species.

[1] *Allgemeine Forst- und Jagd-Zeitung*, 1853, p. 203.

Conduct of Fellings. In Wagner's *Blendersaumschlag* the regeneration fellings are carried out as in the case of the shelter-wood strip system (p. 79), with the important difference that fellings proceed from N. to S. instead of from E. to W. At Gaildorf the strips are laid out with mathematical exactness with the aid of a compass, in lines running due E. and W.; this rule is departed from only in special cases. The regeneration of an area generally begins with the felling of a narrow clear strip along the northern edge of the wood in a good seed-year, and where there is any risk of a heavy growth of grass this strip is at once planted up; at the same time a seeding felling is carried out in the next strip, which is broader. The object of the initial clear strip is to ensure the prompt beginning of regeneration; if the border trees are left in part, their well-developed root-systems tend to hinder the establishment of seedlings.

Seeding, secondary, and final fellings follow each other as in the shelter-wood strip system in general, and mixtures are regulated as already described (p. 81). At Gaildorf great care has to be taken to keep the canopy dense until the moment the seeding felling is carried out, in order to prevent the premature regeneration of shade-bearers, and particularly beech, which tends to usurp the ground to the exclusion of other species; for the same reason, as soon as beech regeneration appears the canopy has to be opened out further in order to admit other species, the young beech being removed if necessary where it is too plentiful. There is no definite rule as to the breadth of each strip; in general, however, Wagner's system involves narrow strips up to about half-tree height or little more. Advance growth is usually cut out at the time of the seeding felling, only promising groups of advance growth, in gaps caused by wind or snow, being left.

Once begun, the strip fellings should advance steadily and without any hiatus; too great a difference in age between the plants on successive strips tends to promote branch-formation, which is undesirable. The progress of the strip fellings varies considerably, and may be hastened or retarded in order to comply with yield requirements and to follow the progress of regeneration. At Gaildorf the average rate of advance in different sections varies from about 1 metre or even less to as much as 10 metres a year, the resulting crop being more even-aged in the latter case than in the former. Where the rate of progress is too slow it may be hastened by increasing the breadth of the strip in which seeding fellings are carried out, and if necessary by hoeing the soil and even by artificial regeneration, preferably in the form of sowing. The number and

the frequency of the regeneration fellings are not absolutely fixed; theoretically there are three successive fellings repeated on the same strip on an average every 3 years. In good seed-years the seeding fellings are pushed on, while in poor seed-years secondary or final fellings are carried out. The aspect of the strip fellings is shown in Figs. 44 to 47, and Fig. 47 shows the method of felling into the old wood in order to avoid damaging the young crop. These illustrations, which are typical, show that the young crops produced are of an even-aged type over appreciable distances, particularly where the rate of progress has been rapid; they are

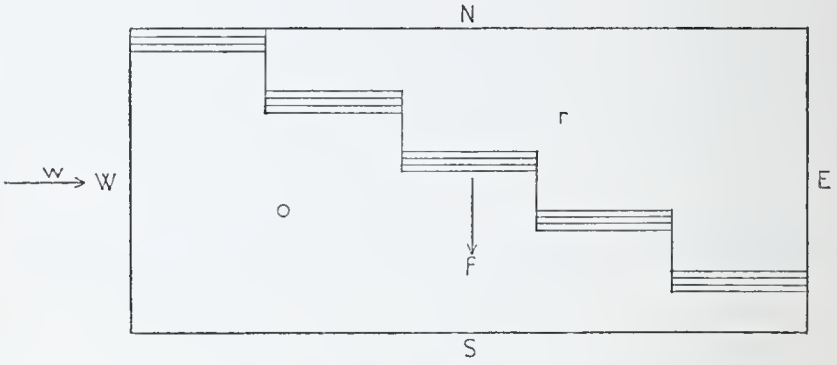

FIG. 48. Wagner's *Blendersaumschlag*. Step fellings advancing from N. to S. giving protection against both sun and wind. *f*, felling direction ; *w*, wind direction ; *o*, old wood ; *r*, regenerated area.

in no sense of the term crops of the selection type, as is sometimes imagined.

Where necessary, protection against the west wind can be secured, while still maintaining lateral shelter from the south, by working in echelon formation as shown in Fig. 48. An example of this formation, termed *Staffelschlag* or *Treppenhieb* (step felling), may be seen in Fig. 44. Where conditions render it desirable that the fellings should advance in a direction between S. and W., narrow openings are made like the teeth of a saw, and the strips advance diagonally in a more or less south-westerly direction, as shown in Fig. 49 (*Buchtenhieb* or bay felling).

In hilly country the direction of the strip fellings has to be arranged in such a way as to provide protection against the sun as well as the wind, and to allow for the extraction of timber down the slopes without passing through regenerated crops. As in the ordinary shelter-wood strip system, this implies a good road system. A simple felling key on the Bavarian pattern, illustrated in Wagner's *Grundlagen*, is shown in Fig. 50; this resembles in some respects

FIG. 44. Wagner's *Blendersaumschlag* in forest of spruce, silver fir, and beech. Strip fellings proceeding towards left (south). Regenerated area on right represents average rate of advance of 7 yards a year. Gaildorf, Württemberg.

FIG. 45. The same. Strip fellings proceeding up slope towards right (south). Road forms boundary of cutting section; area on right of road regenerated in 12 years. Gaildorf, Württemberg.

FIG. 46. Wagner's *Blendersaumschlag* in forest of spruce, silver fir, and beech. View northwards through strip under regeneration across regenerated area to adjoining cutting section. Regenerated area represents progress of 80 yards in 15 years. Note beech regeneration in foreground. Gaildorf, Württemberg.

FIG. 47. The same. View along strip under regeneration, showing method of felling into old wood to avoid damage to young crop. Fellings advancing towards left (south). Gaildorf, Württemberg.

the key illustrated in Fig. 40. A more elaborate felling key is shown in Fig. 20 of *Der Blendersaumschlag und sein System*, 2nd ed., 1915.

In practice, horizontal strip fellings proceeding downhill from S. to N. are sometimes employed on steep shady northern slopes where the soil is sufficiently moist to ensure the survival of seedlings. The forests of Gaildorf are situated on rolling country without any large or steep hills, and the N.–S. direction can be maintained everywhere without difficulty, the fellings advancing uphill where necessary (see Fig. 45).

Form of Crop produced. In the general account of the shelter-wood strip system we have seen that, since it was evolved out of the uni-

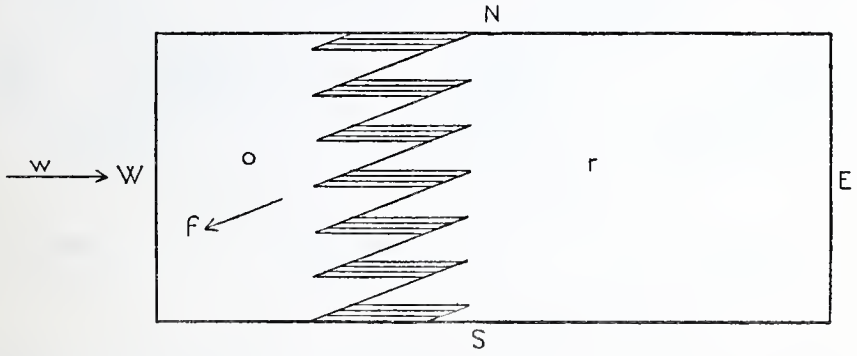

FIG. 49. Wagner's *Blendersaumschlag*. Fellings advancing diagonally towards WSW. *f*, felling direction; *w*, wind direction; *o*, old wood; *r*, regenerated area.

form system, the idea of obtaining more or less even-aged crops over whole compartments has been perpetuated, and in order to effect this object small cutting sections are formed and strip fellings proceed simultaneously through each (see p. 84, and Fig. 42). Wagner's *Blendersaumschlag* has a different object in view: it aims not at even-aged crops over considerable areas, but at uneven-aged crops. In this system the crop is even-aged along the direction of the strip (E. to W.) but uneven-aged from one end of the regeneration area to the other (N. to S.). The ideal form of crop in a single unit is one containing trees of all ages from 1 to *r* (the rotation) arranged in successive strips; in practice such complete units seldom exist, though the more age-classes these units contain, and the shorter they are, the more favourable they are considered to be from a silvicultural point of view. The only exception is on southern slopes and sometimes on steep northern slopes, where horizontal strip fellings advance downhill; here long slopes should be divided into sections by contour roads in order to avoid dragging timber

down through young crops, and the time taken to regenerate a section should not be more than 40 years.

Each unit containing an ascending series of age-gradations from the seedling upwards is called a *Schlagreihe*, for which the English term 'felling unit' may be employed. The *Schlagreihe* is defined as

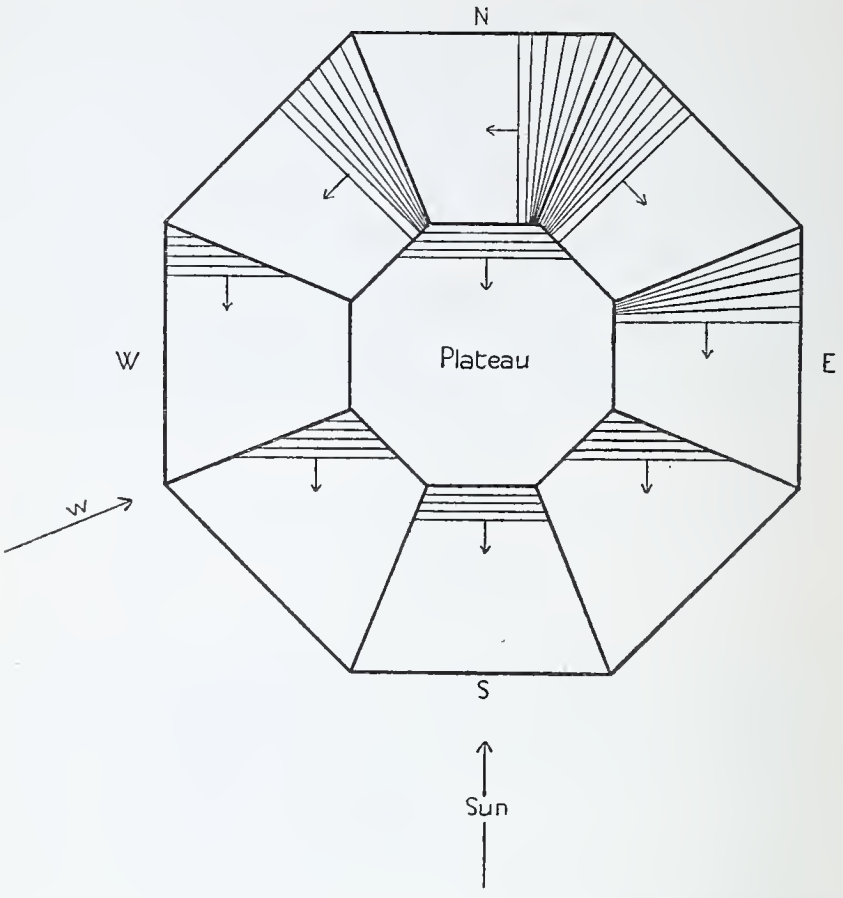

FIG. 50. Wagner's *Blendersaumschlag*. Felling key on the Bavarian pattern, showing arrangement of strips on different slopes with the view of protection against sun and wind. Small arrows show felling direction ; *w*. wind direction. (After Wagner.)

the area between two lines of attack (i.e. strips under regeneration) and is movable, since the strips must be proceeding continuously forward: in Wagner's words, 'the *Schlagreihen* follow each other like the waves of the sea'. These felling units, and the ideal form of crop produced by the *Blendersaumschlag*, can best be appreciated from Fig. 51. This form of crop Wagner terms *geordneter Blenderwald* (organized selection forest), that is, forest containing trees of all ages, like selection forest, but with this important difference, that the age-classes, instead of being mixed together, are regularly

distributed in succession from one end of the area to the other. This arrangement possesses various advantages over the typical *Blenderbetrieb* or selection system: the age-classes can be readily distinguished from each other (an important point in determining the possibility), the progress of regeneration can be more easily watched and controlled, fellings can be easily located and supervised, and damage by felling and extraction is reduced to a minimum.

Although the ideal young crop aimed at is one with a sloping canopy, such as would be produced by a slow rate of progress, actually at Gaildorf the characteristic picture is that of fairly even-aged young crops rather than of steep-sloping canopies, since the rate of progress is affected by such questions as the yield and the

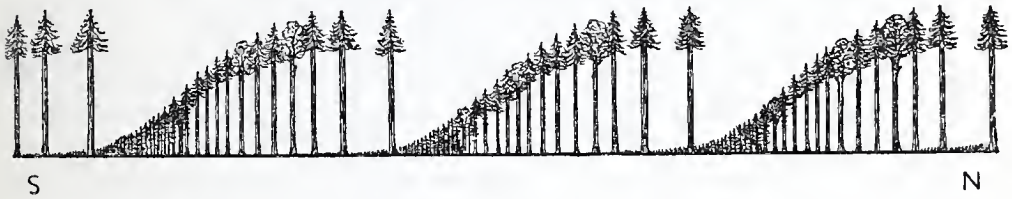

FIG. 51. Profile of a portion of an organized *Blendersaumschlag* forest, showing three felling units. Felling direction from N. to S. (Vertical scale about 10 times horizontal scale.)

necessity for opening the canopy sufficiently rapidly to maintain a mixture of light-demanding species.

The *Blendersaumschlag* idea of producing crops consisting of a series of ascending age-classes in regular succession by means of narrow progressive shelter strips is to be found in the older *Saumfemelbetrieb* of Oberforstmeister Ney, who introduced the system in order to avoid the damage done under the usual selection system by felling large trees over smaller ones. He divided the whole forest into blocks, in each of which all age classes were to be represented, not mixed together as in the selection system, but separated in parallel progressive strips, so that fellings should begin at one end of a block and proceed progressively through it. Ney, however, does not appear to have regarded the sun as a determining factor in regard to the direction of fellings, since he proposed as an alternative to his *Saumfemelbetrieb* a method which he termed *Ringfemelbetrieb*, under which regeneration should proceed not from one end of a block to the other but from the centre outwards in a series of concentric circles. This would doubtless have obviated the felling of large trees over smaller ones, but it would have exposed the gradually widening gap to the effects of both sun and wind. It would have also made any adjustment between the rate of regeneration and the

outturn of timber difficult, if not impossible, since the outturn would tend to increase steadily as the gap widened and the length of the circular strip under regeneration became greater and greater.

Cutting Sections. In describing the *Blendersaumschlag* Wagner uses the term *Hiebszug* (cutting section) in the sense of a permanent definitely bounded area, a unit of management. Taking the term in this sense, the ideal cutting section of the *Blendersaumschlag* is a complete series of age gradations, in which case it is synonymous with a felling unit (*Hiebsreihe*), but actually it may contain two or more felling units. It should be surrounded by roads and bordered on the S. and W. by shelter-belts, preferably of wind-firm broad-leaved species, of which oak is the best. In hilly country the boundaries of cutting sections should be along the ridges and down the spurs, not down the ravines separating the spurs.

In laying out cutting sections for the first time, one or more felling units extending right across them from E. to W. should be formed in such a way that as far as possible the older crops are placed in the northern part of each felling unit and the younger crops in the southern part, the general sequence of age-classes descending from N. to S. Otherwise the length of each felling unit is determined according to the probable progress of natural regeneration. It is a good maxim to keep the number of felling units in a cutting section down to a minimum, as this facilitates supervision; in other words, the number of age-classes represented in the ideal felling unit should be the largest possible.

Cutting sections and compartments should coincide as far as possible, and in laying out a new area the former should be determined first and the latter then made to conform to them. Where well-defined compartments already exist, cutting sections should, as far as is practicable, be made to coincide with them. The usual size of a cutting section may be taken to be about 30 to 50 acres. At Gaildorf the most suitable length for a felling unit is considered to be 300 metres, and this is perhaps a better criterion than area.

Application of System. The principles enunciated by Wagner, particularly in regard to the adverse effects of the sun, and the advantages of felling in narrow strips from N. to S., have had a profound effect on European forestry during the past decade or two, particularly in Central European countries, where *Blendersaumschlag* principles in one form or another have been applied in many different localities, sometimes, it must be admitted, with insufficient reason. The system is not always applied in the ideal form described by Wagner, almost any form of strip or strip and group felling

from N. to S. being designated *Blendersaumschlag*. Often small cutting sections on the Württemberg plan are formed with the object of regenerating whole compartments in a limited period of years. A modification of the system has proved successful in the Scots pine and spruce forests of Finspong, Sweden. As has already been pointed out, the idea of working to the compass is one which is capable of wide application, and it may yet be the means of solving problems of regeneration in many parts of the world.

4. THE STRIP AND GROUP SYSTEM

General Description. The strip and group system is a modification of the shelter-wood strip system, and bears the same relation to it that the group system bears to the uniform system. The German term is *Saumfemelschlag*, and the system is sometimes alluded to as the Bavarian *Saumfemelschlag* or Von Huber's method, from the fact that in the first instance it was developed chiefly in Bavaria, by Von Huber. The general scheme of cutting sections and strips is the same as that of the shelter-wood strip system, but the fellings are carried out in a different manner. In the initial strip a seeding felling is carried out consisting of an even opening of the canopy in the usual way together with the freeing of any groups of advance growth in gaps caused by wind or snow. At the same time further groups of advance growth are sought for and freed for some distance ahead of the initial strip, while if necessary further gaps are created artificially in order to induce more groups of advance growth to appear; these groups of advance growth are enlarged from time to time as in the group system. Meanwhile the strip fellings advance steadily, absorbing the groups of advance growth, and new gap fellings are also pushed on some distance ahead of the strip fellings, until the end of the working section is reached. Fig. 52 shows diagrammatically the progress of fellings under the strip and group system. In some cases group fellings are made all over a cutting section before the strip fellings are begun, and the latter are largely in the nature of removal fellings. The progress of the fellings, and the form of the strips, is less regular under this system than under the shelter-wood strip system, as may be seen from Fig. 53.

The strip and group system is well adapted for the regulation of mixtures, on the lines already indicated for the group system (pp. 66–8). Shade-bearers may be introduced artificially in small gaps ahead of the strip fellings; beech is frequently introduced in this way into coniferous forests, the conifers being afterwards re-

generated naturally by strip fellings. Seed-bearers of light-demanding species are generally retained on the strips until the final felling, in order to seed up gaps, or such species may be introduced artificially on the strips when they have been opened out.

The strip and group system is widely practised in various parts of Central Europe, particularly in Austria, Czechoslovakia, and Bavaria, as well as in parts of Baden and Württemberg. A modification of the strip and group system is practised in Switzerland and to some extent in Baden, strip fellings being carried out in conjunc-

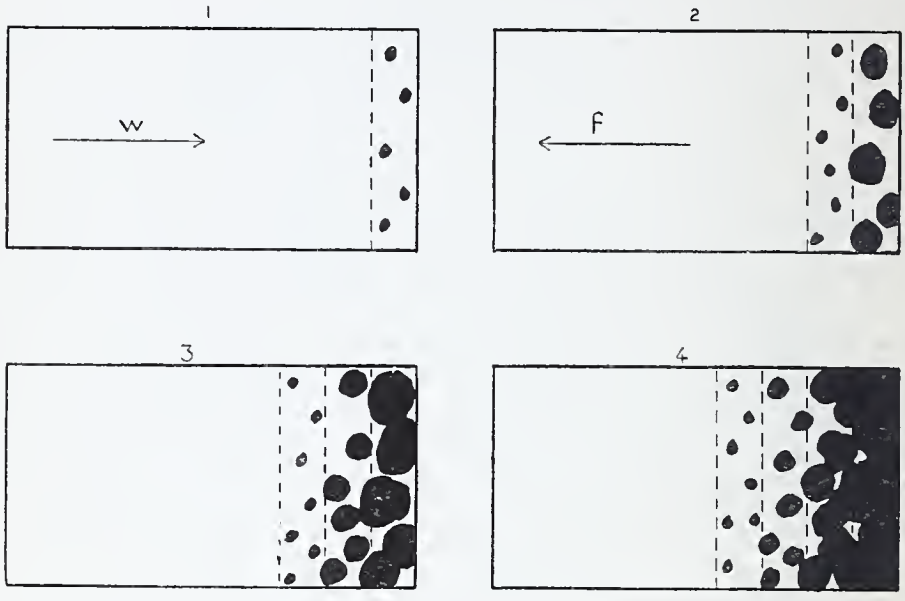

Fig. 52. Strip and group system, showing progress of felling against the wind. Regenerated areas in black. *f*, felling direction ; *w*, wind direction.

tion with the Swiss or Baden *Femelschlag* system. The procedure is to bring regeneration to an advanced stage by irregular shelter-wood fellings for some distance ahead of the strip fellings, and to employ the latter for the final removal of the remaining seed-bearers; by this means the regeneration of light-demanders like Scots pine and larch can be accomplished by retaining seed-bearers of these species for a time on the strips. Fig. 54 shows the appearance of a strip felling of this kind.

Comparison with Shelter-wood Strip System. The strip and group system possesses certain advantages over the typical shelter-wood strip system similar to those possessed by the group over the uniform system. Regeneration can be accomplished with greater certainty and rapidity owing to the establishment of groups of advance growth ahead of the strip fellings, and the uneven-aged

form of the young crop serves to some extent as a protection against snow and wind. Mixtures can also be regulated more easily. On the other hand there is considerable risk of damage to the groups of advance growth during the extraction of timber, particularly on steep slopes.

5. THE PROGRESSIVE CLEAR-STRIP SYSTEM

A clear-strip felling in the sense in which it is used in this section is a clear-felling in the form of a strip so narrow that the adjoining old wood, through the lateral shade or protection afforded by it, exercises a direct influence on the strip and may thus produce a marked effect on the survival of seedlings and the establishment of regeneration, whether natural or artificial. The width of a strip of this kind generally varies from half the height to the full height of the trees of the old wood. Such a strip should have the full advantage of the favourable influence of the adjoining old wood, otherwise the felling ranks as a strip-like clear felling.

The German term for such a narrow clear-strip felling is *Kahlsaumschlag*, in contradistinction to *Kahlstreifenschlag*, which denotes the felling of a clear strip (*Streif*) of some breadth.

Generally speaking, clear-strip fellings are employed in order to secure the advantages of side protection from the sun where this is found to be beneficial, and the strips advance in a general N.–S. direction. The arrangement of cutting sections and fellings is similar to that of the shelter-wood strip system or Wagner's *Blendersaumschlag*, except that the strips are clear-felled and regenerated naturally from the adjoining old wood, or if necessary artificially; the next strip is not felled until the regeneration of the previous one is established. Dr. Wiedemann's investigations mentioned on p. 93 tend to show that narrow strip fellings from N. to S., with intervals of some years between adjacent coupes, are not always suitable for Scots pine.

The progressive clear-strip system arose out of the progressive clear-cutting system with natural regeneration from adjoining woods. This latter system, with long narrow coupes and a felling direction against the wind, is a very old one and was at one time much in use, but the idea of employing narrow strips for protection against the sun is a later development. The progressive clear-strip system is employed chiefly for spruce and Scots pine, and may still be seen in certain places in Bohemia and other parts of Central Europe, with artificial or natural regeneration. Where natural regeneration is relied on it is far less commonly practised at the present day than

the shelter-wood strip system, owing to the greater risk of failure in regeneration and of soil deterioration and weed-growth.

6. THE ALTERNATE CLEAR-STRIP SYSTEM

Fellings in alternate clear strips are known in French as *Coupes par bandes alternes*, in German as *Kulissenhiebe*, *Springschläge*, or *Wechselschläge*. In its usual form the alternate clear-strip system consists of cutting parallel clear strips through the forest, usually up to 100 feet wide, leaving intervening untouched belts of equal width between these strips. The clear strips are regenerated artificially, and the young crops benefit from the lateral protection of these belts. When the young crops on the regenerated strips are fully established and out of danger from frost or drought, the intervening belts are felled and regenerated artificially. This system is employed to some extent as a protection against late frosts on the Rhine–Main plain in Germany. Its chief use is for the introduction of tender species in mixture with existing species, strips being generally more convenient than groups for this purpose.

A less common method is to allow the young crop, established on the clear strips by artificial or natural regeneration, to grow up until it is high enough to afford lateral protection in its turn, when the intervening belts of old wood are felled and regenerated. This procedure has not found much favour, and has been generally abandoned in Europe. Although effective from the point of view of protection, it is somewhat difficult to work in practice owing to the long lapse of time—40 to 50 years or more—between the two fellings, and the consequent difficulty of keeping trace of the strips. Along the edges of the old strips, again, the young plants tend to become suppressed and to die off, particularly in the case of light-demanders.

Alternate clear-strip fellings have been practised in Germany for a long time. They are referred to, among other methods, in the Hesse-Kassel Ordinance of 1761, and many writers of the nineteenth century mention them. They appear to have been more in use at one time than they are at present.

FIG. 53. Strip and group system in forest of spruce and silver fir. Fellings proceeding from left to right downhill and against the prevailing wind direction. Schifferschaftswald, Baden Black Forest.

FIG. 54. Strip felling in combination with Swiss *Femelschlag* system in forest of spruce, silver fir, and beech. Fellings proceeding from right to left. Eschenberg forest, Winterthur, Switzerland.

VIII

THE WEDGE SYSTEM

1. ORIGIN AND DEVELOPMENT

A SYSTEM termed the wedge system or shelter-wood wedge system (*Keilschirmschlag*) has come into prominence in recent years. The suggestion to make cuttings in wedges pointing towards the prevailing wind direction, in order to diminish the risk of damage by wind, was first put forward in 1903 by Oberförster Eifert in a paper[1] giving the results of a study of wind conditions in the north-eastern Württemberg Black Forest. Eifert's suggestion was put into practice in the forests of Langenbrand, in the same region, by Dr. Eberhard, the Forstmeister in charge, and successful results have been achieved there. Wedge fellings have since been elaborated and systematized on a more extensive scale by Dr. Karl Philipp, who, when Forstmeister in charge of the forests of Huchenfeld (Baden Black Forest), tested them in practice in that locality; subsequently, as Chief of the Baden Forest Service, he has been instrumental in extending the wedge system generally throughout the forests of Baden.

Wedge fellings in the earlier stages of their development were applied, as in Langenbrand and Huchenfeld, to forests consisting chiefly of silver fir, spruce, and Scots pine, situated in hilly country where the climate is somewhat cold and rough and the normal rainfall is between 35 and 40 inches; westerly and south-westerly gales are a constant source of danger, and in the first instance one of the chief objects of these fellings was to minimize the risk of damage from this source. More recently, however, the wedge system has been introduced into forests of Scots pine mixed with hornbeam, beech, oak, and other hardwoods on the plains of the Rhine, where damage from storms is a far less serious factor.

2. GENERAL DESCRIPTION

The wedge system is a form of strip system in which the fellings, instead of starting at one end of a cutting section and proceeding to the other, begin by a strip in the centre of it and proceed outwards in both directions. The main objects aimed at are (1) to shorten the haulage distance to the nearest road, (2) to present a longer front to regeneration than in the usual shelter-wood strip system and

[1] *Forstliche Sturm-Beobachtungen im Mittelgebirge : Allgem. Forst- u. Jagdzeitung*, 1903, pp. 323, 369, and 413.

thus to ensure greater elasticity, and, if necessary, greater speed, in the progress of the fellings, (3) to minimize damage from storms, (4) to avoid damage to the young crop during the felling and extraction of timber.

In practice great stress is laid on certain measures, not peculiar to this system, for promoting and completing regeneration: these include (1) frequent light thinnings throughout the life of the wood, increasing in frequency to intervals of 1 to 3 years in the later stages,

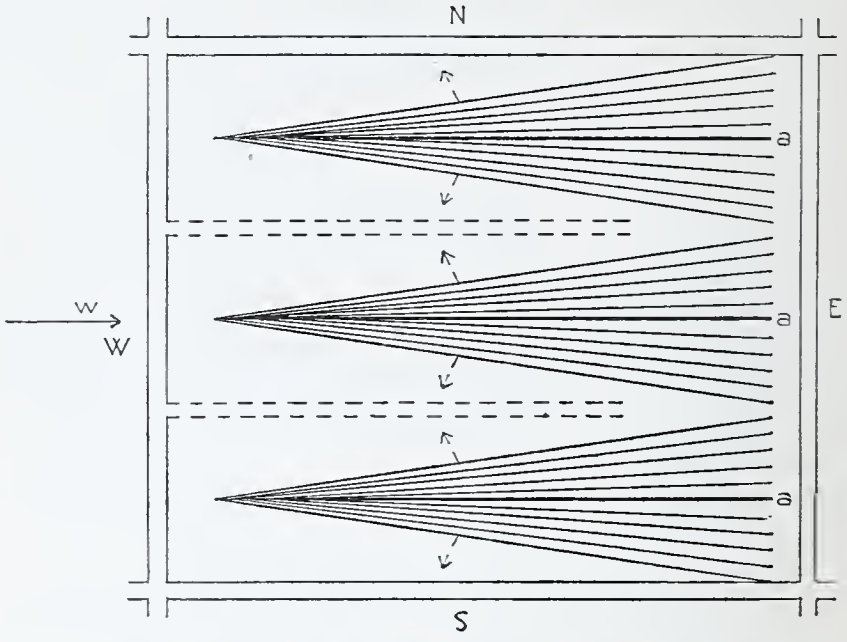

FIG. 55. Wedge fellings on level ground, showing original strips (*a*, *a*) and subsequent enlargements. *w*, wind direction. Temporary cart-tracks shown by dotted lines. Dotted arrows indicate direction of timber extraction.

until the regeneration of shade-bearers begins to take place; (2) the removal of raw humus or the working of the soil, where necessary, in order to stimulate natural regeneration; (3) the rapid removal of the old crop as soon as regeneration appears over the area. Thus in effect the wedge fellings are largely in the nature of removal fellings over an area already partly regenerated, and the more rapidly the removal can be effected the better. On the plains of the Rhine, in forests of Scots pine mixed with hardwoods, whole compartments are regenerated in 6 to 8 years; in the Black Forest, where spruce and silver fir predominate, the period is usually longer.

The wedge fellings are carried out in the following manner:

FELLINGS ON LEVEL GROUND OR GENTLE SLOPES (see Fig. 55). Parallel lines running E.–W. or NE.–SW., in the direction of the prevailing

FIG. 56. Wedge system in forest of spruce, silver fir, and Scots pine. View towards west from base to apex of wedge. Langenbrand, Württemberg Black Forest.

FIG. 57. Wedge system in forest of spruce, silver fir, and Scots pine. View down wedge towards base; regeneration well advanced. Langenbrand.

FIG. 58. Wedge system in forest of Scots pine with hornbeam and other hardwoods on the Rhine plains. View from apex towards base of wedge.

wind, are laid out at intervals usually of 80 metres through the compartment to be regenerated; these are felled to a width of 6 to 15 feet, and form the initial strips. Protective belts of forest are left at each end of the felled strips. Midway between the initial strips, and parallel to them, temporary cart-tracks are laid out leading to permanent roads bounding the compartment. Subsequent fellings consist of widening the initial strips by progressive narrow strip fellings carried out at frequent intervals, not parallel to the initial strips but at a slight angle to them, so as to form gradually widening wedges with their apexes pointing towards the

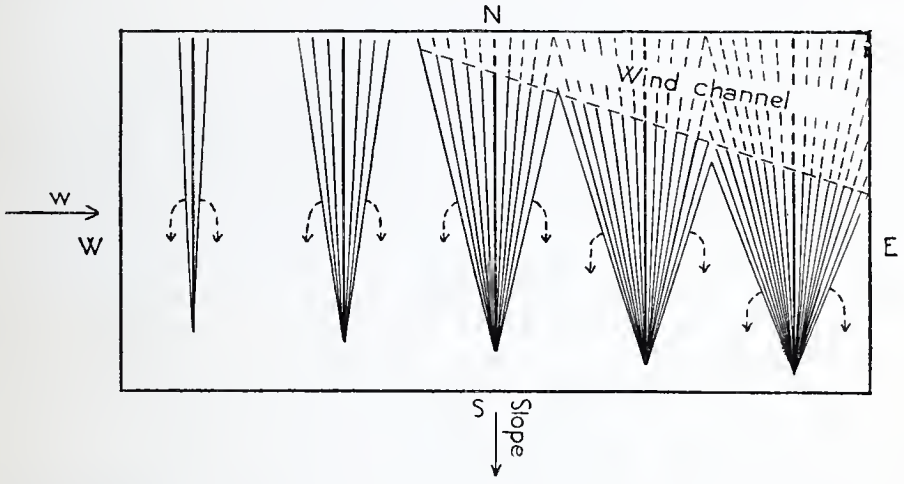

FIG. 59. Wedge fellings on a southern slope. Dotted arrows indicate direction of timber extraction. *w*, wind direction.

prevailing wind direction; at the same time their apexes are pushed forward towards the edge of the regeneration area. Seed-bearers of light-demanding species, particularly Scots pine and larch, are left for a time to regenerate gaps as the wedges are opened out. Eventually the wedges join up, and the shelter-belts are removed by strip fellings, so that the whole area becomes regenerated. The last trees to be felled are those along the sides of the permanent roads; a few of these, usually Scots pine, are left to put on increment and to act as seed-bearers for the regeneration of blanks. Different stages in the progress of wedge fellings are shown in Figs. 56, 57, and 58.

FELLINGS ON STEEP SLOPES (see Fig. 59). Here the procedure has to be modified to facilitate the extraction of logs downhill. The initial strips are cut vertically up and down the slope, and the wedges are widened in such a way that their apexes point downhill. As shown in Figs. 55 and 59, fellings begin in the east of an area and continue successively towards the west, in order to retain protection from the

west wind as long as possible. After the wedges join up a gradually widening wind channel is formed along their bases, on the upper part of the slope.

Referring to Fig. 55, the following points may be noted:

1. In each compartment there is a long cutting edge under regeneration.

2. The haulage distance to the nearest cart-track is short.

3. The northern side of the wedge is exposed to the sun; in dry situations this might have an adverse influence on natural regeneration.

It is claimed that wedge fellings tend to reduce the risk of damage by wind. Thus in the plan adopted on level ground (Fig. 55) the wind enters the narrow end of the wedge and is dissipated as it passes through it. On westerly slopes the same happens. On easterly and north-easterly slopes the point of the wedge has to be opened out so that there is a clear lane from top to bottom of the slope, which permits descending winds to pass through. On northerly and southerly slopes the wind channel formed by the widening of the wedges serves the same purpose. In order to ensure the correct alignment of wedges in regions subject to storms, Dr. Philipp has constructed a special felling key for the wedge system, based on a careful study of wind conditions on different aspects in the forests of Huchenfeld.[1] Where wind is not a source of danger the alignment of the wedges may be made without regard to the prevailing wind direction, and is governed by such considerations as the shape of the area to be regenerated and the situation of roads.

3. RESULTS OBTAINED

The results obtained so far by the wedge system, both in the Black Forest and on the plains of the Rhine, are encouraging. The long front exposed to regeneration enables the old crop to be removed rapidly, and the extraction of timber can be carried out cheaply, methodically, and with little or no damage to the young crop. Those who have practised the system maintain that by the careful alignment of wedges in accordance with the prevailing wind direction a considerable diminution can be effected in the amount of damage done by wind.

[1] The felling key is figured in the following two publications:

1. K. Philipp, *Die Umstellung der Wirtschaft in den badischen Staats-, Gemeinde- und Körperschaftswaldungen*, Fig. 1, p. 75 (Karlsruhe, J. Lang, 1926).
2. K. Philipp and E. Kurz, *Die Verjüngung der Hochwaldbestände*, Fig. 4, p. 49 (J. Lang, 1926).

IX

THE SELECTION SYSTEM

1. TERMINOLOGY

The selection system differs from all the systems previously described in that felling and regeneration are not confined to certain parts of the area but are distributed all over it, the fellings consisting of the removal of single trees or small groups of trees scattered throughout the forest. Fellings carried out in this manner are termed 'selection fellings': they result in an uneven-aged type of forest in which all age-classes are mixed together over every part of the area. This completely uneven-aged type of forest is usually termed 'selection forest', or 'forest of the selection type', whether it has actually been produced by selection fellings or not.

The French equivalent for the selection system is *jardinage*. The term *furetage*, at one time applied to rough-and-ready selection fellings of any kind, is now generally applied to selection fellings in coppice (see p. 143).

The German terms in use are as follows:

Plenterbetrieb, *Femelbetrieb*, *Schleichwirtschaft* (selection system).

Plenterhieb, *Femelschlag* (or *-hieb*), *Blenderschlag* (selection felling); *Plenterwald*, *Femelwald* (selection forest). *Waldgärtnerei*, sometimes applied to selection fellings in small private properties.

There is some difference of opinion among German writers as to the exact significance of the terms *Plenter-* (*Blender-*) and *Femel-*. From about 1760, according to Bühler,[1] the selection type of forest has been termed *Plenterwald*, or in South Germany *Femelwald*, and the single stems cut out are said to be *geplentert* or *gefemelt*. He also states[2] that the word *plentern* began to be used all over Germany about 1787, and that it means the cutting out of single trees and also single suppressed and dead stems, whereas *femeln* applies only to the removal of exploitable trees. Philipp[3] also maintains that in the *Femelbetrieb* the chief consideration is the question of dimension or utilization, that is, the cutting of trees of a fixed minimum size, and that Heyer first used the term to denote irregular fellings of any kind. Jeitter[4] refers to *Bländerschläge* as fellings in which exploit-

[1] *Der Waldbau*, vol. ii, p. 575, 1922 and 1927. [2] Ib., p. 578.

[3] *Richtlinien für Erziehung und Verjüngung der Hochwaldungen in Baden*, p. 19, 1925.

[4] *Forstkatechismus*, 1806.

able trees in particular are cut out. At the present day *Plenter-* (*Blender*) and *Femel-* are usually taken to be synonymous, and denote selection fellings in general; Mayr, Wagner, and others adopt this view, which seems to be the rational one under modern usage.

2. GENERAL DESCRIPTION

Felling and Regeneration. Under the selection system scattered single trees or small groups of trees are selected over the whole area and removed; where conditions are favourable, natural regeneration springs up in the gaps so created. Under ideal conditions this process goes on year after year over the whole forest, the volume removed being fixed by rules of management; this results in the

FIG. 60. Forest worked under the selection system.

constant maintenance throughout the whole area of an uneven-aged type of forest ('selection forest') in which trees of all ages are mixed together. Theoretically a forest worked under the selection system should contain all age-classes distributed over the area in correct proportion of stems. Such regularity is seldom actually found, the age-classes occurring more usually in small groups, resulting from groups of regeneration springing up in gaps. The appearance of forest worked under the selection system is shown in Figs. 60 to 63.

The selection and felling each year of scattered trees over the whole forest would be impracticable except in areas of small size, and hence in Europe this procedure is usually confined to small forests belonging to private persons or communities. In forests of larger size it is customary to divide the area into a number of more or less equal blocks, in one of which selection fellings are carried out each year, so that the whole forest is worked over during a period of years equal to the number of blocks into which the area is divided. This period is known as the 'felling cycle'. Under this arrangement fellings are more concentrated, there being an accumulation of mature trees during the interval between two successive visits to the same block, so that a larger volume per acre is

available for felling over the annual coupe than in the case of annual fellings extending over the whole forest.

The term 'ideal selection system' is sometimes employed in reference to fellings carried out over the whole area each year, while the term 'periodic selection system' refers to fellings carried out under a felling cycle.

In their most primitive form selection fellings consist of removing all trees which have attained a certain diameter or girth, sometimes with the proviso that any trees required as seed-bearers should be retained. Such fellings are mere 'exploitation fellings', requiring little or no silvicultural skill; they do not ensure regeneration, nor do they provide for a regular sustained yield. Hence if selection fellings are to be raised to the status of a silvicultural system, something more is required than the mere mechanical removal of exploitable trees. It is necessary also to provide for sustained yields by carrying out thinnings among the various age-classes in order to ensure that these are maintained in their correct proportions, that a suitable mixture is maintained if necessary, that young saplings are freed from suppression, and that defective stems of any size are removed wherever they are hampering better ones. Hence wherever the selection system is worked as a true system, thinnings among the immature stems are carried out along with the felling of trees of exploitable size, the whole forming one operation; cleanings are also carried out amongst the younger age-classes, and measures to assist regeneration may extend to the removal of raw humus, the working of the soil, and even sowing and planting in gaps caused by felling or otherwise.

Fellings under the selection system generally involve the removal of the following classes of trees:

1. Dead and dying trees.

2. Trees which are diseased, misshapen, or otherwise defective or lacking in vigour, or of undesirable species, particularly if interfering with better stems or promising groups of young growth.

3. Trees of exploitable size, particularly if defective or lacking in vigour.

In modern practice the tendency is to abandon the idea of an exploitable diameter, and to leave specially vigorous well-shaped trees of any size to put on increment.

In order to secure a correct distribution of size-classes, a plan sometimes adopted is to construct a graph representing, as nearly as can be estimated, their normal distribution, and to carry out the fellings in such a way as to lead gradually towards the normal;

a comparison of the actual distribution of size-classes with the normal curve serves as a guide, the fellings being confined as far as possible to those size-classes which are in excess.

Group Selection Fellings. The typical form of selection fellings, in which single trees are removed, is suitable for shade-bearing rather than for light-demanding species, since the gaps created by the removal of single trees are too small for the healthy regeneration of light-demanders, or for the smaller trees to escape suppression from the larger ones standing over them. Hence if the selection system is to be applied to light-demanders, it is necessary to fell trees in groups in order to create gaps of sufficient size to enable regeneration to establish itself. Such fellings are known as group selection fellings, and the modification of the selection system under which this type of felling is employed is termed the 'group selection system' (Ger. *horstweiser Femelbetrieb*). It is employed to some extent for spruce, and is practised in the larch forests of the Alps and in the Corsican pine forests of Corsica. Group selection fellings have been employed in the coniferous forests of the NW. Himalaya, and in the sal and other types of broad-leaved forest in India, sometimes as a transition towards some more even-aged system.

The Felling Cycle. (Fr. *Rotation*, Ger. *Hiebsumlauf*.) This cycle should be fixed according to the requirements of each case. If it is very short, involving large coupes, the cultural advantages of the selection system—including cleanings and thinnings—have full play, but work is scattered and therefore costly. If it is very long, involving small coupes, fellings over definite coupes become intensive, larger quantities of timber being removed over a restricted area; this is an advantage from the economic point of view, and it may also favour the regeneration of light-demanders through the creation of large gaps, but the cultural advantages are to a great extent lost, while the accumulation of large trees upsets the correct distribution of size-classes and destroys the character of true selection forest.

In Europe the felling cycle is generally not more than 10 years, and is often less; in France it is usually between 5 and 8 years, seldom if ever more than 8 years, while in the beech forests of the Chilterns in England it varies as a rule between 6 and 12 years. In India and Burma the felling cycle generally varies from 10 to 30 years in the case of selection fellings of a primitive kind.

In Europe a definite felling cycle is sometimes dispensed with in coniferous forests in regions where frequent windfalls necessitate the quick removal of fallen timber in various parts of the forest;

FIG. 61. Spruce and silver fir forest under the selection system. Forest of La Joux, French Jura.

FIG. 62. Forest of spruce and silver fir under the selection system. Forest of Couvet, Switzerland.

FIG. 63. Forest of spruce and silver fir under the selection system. Oberwolfach, Baden Black Forest.

under such conditions a prearranged felling cycle with definite annual felling areas would be inadvisable. This procedure would be difficult, if not impossible, over extensive forests where close personal attention could not be exercised.

3. ADVANTAGES AND DISADVANTAGES OF THE SELECTION SYSTEM

In considering the advantages and disadvantages of the selection system, it must be understood that this refers to the system as applied in its true form with fellings in all size-classes, and not to the mechanical removal of trees which have attained a certain diameter. On this understanding the chief advantages and disadvantages may be stated as follows:

ADVANTAGES: 1. By maintaining a constant forest cover the continued fertility of the soil is ensured, protection is afforded against erosion, landslips, and snow-slides, and seedlings are well protected against the effects of sun, frost, and cold winds.

2. All seed-years are made use of, and the good crown development of the trees produces good seed-bearers; this promotes conditions favourable to regeneration, at all events that of shade-bearers.

3. Damage by wind and snow is minimized by the uneven-aged condition of the stand, the larger trees protecting the smaller ones, and by the good development of crowns and root-systems; the superiority of this system as regards windfall, however, is denied by some writers.[1]

4. From the aesthetic point of view the selection system has a special advantage owing to the absence of clearings of any kind and to the fact that uneven-aged woods have a more artistic appearance than even-aged woods.

DISADVANTAGES: 1. Owing to the scattered nature of the fellings, their supervision is difficult and the cost of felling and extraction is higher than under any other system.

2. Cultural operations, such as cleanings and supplementary artificial regeneration, are likewise difficult and costly owing to the fact that regeneration is more scattered than under any other system.

3. Much injury may be caused to the younger trees and saplings during the felling of large trees and the extraction of timber;

[1] Statistics have been produced which show that in some localities a large percentage of the annual outturn in selection forests is obtained from windfalls. While such statistics may be quite reliable, it should be remembered that the selection system is often adopted for protective reasons in exposed situations where gales are frequent; under such conditions the outturn from windfalls is bound to be high under any system.

damage by felling can be avoided to some extent by first lopping off branches, but this enhances the cost and danger of the work.

4. The selection system is the most difficult of all systems to apply correctly in practice owing to the difficulty of deciding on and maintaining the correct distribution of age-classes, and of determining whether or not regeneration is taking place to the extent necessary to safeguard the outturn of the future.

5. From the management point of view, the correct determination of the yield is more difficult and uncertain than in the case of systems aiming at the regeneration of definite areas in a given period of time.

6. The timber produced by the selection system is inferior in quality to that produced by the more even-aged systems: in the first place, the stems are more tapering and branchy, and in the second place, the growth is more irregular, since the trees are under suppression during the earlier stages and are more or less isolated during the later stages, with the result that the centre consists of narrow-ringed and the outer portion of broad-ringed wood; the wood is thus uneven in texture and contains numerous large knots, and the percentage of utilizable timber of good quality is less than in the case of trees grown in even-aged forest.

7. Where grazing is practised the selection system is not suitable, since regeneration takes place all over the forest, and is not confined to definite areas from which animals may be excluded, as in the case of other systems; in practice this objection may be got over to some extent by closing certain blocks for regeneration in rotation, but in this case the true character of selection forest is lost.

Varying opinions. There are certain points on which opinions differ as regards the merits or defects of the selection system. Among these may be mentioned the following:

1. It is frequently held that fire is less destructive in selection forests than in even-aged forests, since although the younger trees may be killed the older ones survive to regenerate the area. This is not necessarily the case. It is true that young even-aged coniferous crops are often completely destroyed by fire, but on the other hand well-stocked even-aged crops in the pole or tree stage—in which the crowns are well above the reach of any surface fire and the undergrowth is sparse—frequently escape with slight injury. In uneven-aged forests the case is different; with inflammable trees like pine a surface fire may climb up the smaller trees into the crowns of the middle-sized and large ones, developing into an intense crown fire which may destroy the whole forest. Where such a risk

is to be feared it would seem preferable to adopt an even-aged system where special fire-protective measures may be concentrated on young crops, and if necessary to leave seed-bearers as standards over these crops in order to regenerate areas destroyed by fire.

2. The question whether or not the selection system produces higher outturns than the more even-aged systems is one which has been much debated but has never been satisfactorily settled. Figures have been produced to demonstrate the high yields obtained from selection forests, but these have to be accepted with caution, since owing to the difficulty of determining the true possibility it is never certain whether such yields represent only the increment of the forest or include also excess capital removed in fellings. A true comparison between the outturns from selection and even-aged forest respectively will be impossible until figures are available which are based on increment investigations carried out over a long series of years in exactly similar localities. Such figures do not exist at present. It is, in fact, not improbable that whatever the total outturn of wood may be, the outturn of sawn timber of good quality obtained from forests worked under the selection system will be found to be smaller than that obtained from forests worked under even-aged systems.

3. It is sometimes claimed as an advantage for the selection system that it is the most natural one, in that the selection type most nearly resembles virgin forest. If the latter assumption is correct, the implication is that the best way to treat a forest crop is to leave it as far as possible to Nature. But neither the farmer nor the gardener allows Nature to run riot; both take such measures as they can to improve the quality and increase the outturn of their field or garden crops. Why then should not the forester adopt such means as lie in his power to effect the same object in regard to his forest crops?

But in any case the assumption that the selection type of forest is the most natural one is by no means necessarily correct. Certain types of primeval forest, chiefly of evergreen shade-bearing species in the moister tropical regions, maintain themselves in an uneven-aged condition which may or may not resemble that of selection forest; actually, however, virgin forest usually contains a great excess of the older age-classes. The virgin forests of Douglas fir and other coniferous species of western North America tend towards the even-canopied type, or are at most two-storied, and the same applies to many of the coniferous forests of the Himalayan region. There are many types of natural forest in both tropical and temperate regions which regenerate in even-aged masses without the inter-

vention of man, and fail to regenerate successfully in any other way. The real selection type of forest, containing trees of all ages properly distributed, is exceptional even in virgin tropical forest, and requires the careful intervention of man to maintain it; from this point of view, therefore, the true selection type may be regarded as of an artificial rather than of a natural character.

Very divergent opinions have long prevailed as regards the merits of the selection system. Selection fellings have been condemned on many occasions from the Middle Ages onwards. Several German writers of the eighteenth century condemned the selection system because it caused damage in felling and because it removed the best trees; the latter objection obviously referred to fellings of the exploitation type. A Darmstadt Ordinance of 1776 prohibited it altogether, and in 1787 it was laid down in Prussia that even-aged crops should be grown, in order to produce even growth. G. L. Hartig and Cotta, in the end of the eighteenth and beginning of the nineteenth centuries, were definitely antagonistic to the system. The Baden Forest Law of 1833 prohibited the selection system, and this prohibition is still on the statutes, though it is now ignored. In 1883 the French administration directed that the selection system should be regarded as the exception, and that the uniform system should be adopted as a general rule unless there were special reasons against it. Throughout the nineteenth century and up to the present time the controversy 'selection *v.* even-aged systems' has continued, some writers condemning the selection system, others upholding it; at the present day it still has its adherents and its opponents, although the general opinion in most parts of Europe is that it should not be adopted except under special circumstances, such as those mentioned in the next section.

4. APPLICATION OF THE SELECTION SYSTEM

Conditions of Application. Selection fellings, whether in the form of a well-regulated system or otherwise, are generally applied in the following cases:

1. Where, owing to danger from windfall and snowbreak, it is considered advisable to promote the development of individual stems, to secure an uneven-aged form of crop, and to avoid drastic openings in the canopy and the isolation of seed-bearers.

2. To afford protection against erosion, landslips, and avalanches in mountainous regions, to conserve the water-supply in catchment areas and to prevent floods; forests maintained for such purposes are termed 'protection forests'.

3. In small areas where intensive working and close personal attention are possible, and where there is a small regular local demand for produce of different sizes, as in the case of private and village forests in many parts of Europe, which are frequently worked under this system; as a properly regulated system, the selection system is unsuitable for very extensive areas owing to the difficulty of applying it correctly.

4. Where seeding is rare and spasmodic, and it is difficult if not impossible to systematize regeneration to any extent; in such cases the selection system may be employed to take advantage of any fortuitous patches of regeneration that may appear.

5. On broken, precipitous, or rocky ground where continuous regeneration is out of the question, and where advantage has to be taken of scattered regeneration appearing in places where there is sufficient soil to support tree-growth.

6. Primitive exploitation fellings of the selection type are carried out in tracts, usually of large extent or in somewhat inaccessible situations, where only the largest and best trees, or only one or a few species out of many, will pay for removal; such fellings should,where possible, be regarded as a temporary expedient pending the improvement of communications and the development of markets.

7. Selection fellings are applied in certain mountain regions, particularly the Alps, in conjunction with pasturage; the forest is often of a somewhat open type unlike well-stocked selection forest, and the grazing interferes with the proper application of the selection system.

8. The selection type of forest is often maintained for aesthetic reasons in the immediate neighbourhood of towns and villages.

Economic considerations sometimes limit the application of the selection system even in mountainous regions where its adoption might otherwise be indicated, for instance where it is necessary to extract large quantities of timber from a limited area in order to justify the construction of special export works.

So far as species are concerned, in continental Europe the silver fir is better adapted for treatment under the selection system than any other species. It is strongly shade-bearing, has good power of recovery after suppression, and is sensitive to frost during youth. The most typical selection forests of Europe, therefore, consist of silver fir, often with a mixture of spruce or beech or both.

Application in Practice. The highly organized and difficult selection system practised to-day in Europe arose out of selection fellings of a primitive kind, which are probably the oldest form of high forest

working known, and appear to have been practised by the ancients. In France the only high forest system up to the thirteenth century appears to have been that known as *furetage*, which was applied to broad-leaved forest and consisted of unregulated selection fellings under which single trees were removed here and there. These fellings were difficult to control and led to abuses, with the consequence that cutting by area (*par assiettes*) began to be introduced under government ordinances about the beginning of the fourteenth century. In modern times the selection system, suitably regulated, has been practised to a greater or less extent in the mountain forests of France. In the latter part of last century it received an impetus through the failure of the uniform system when applied rigidly with fixed periodic blocks in mountainous regions subject to storms. In consequence of this failure it was decided that the selection system was the only one applicable to those regions, and an ordinance of 1883 gave effect to this decision. Since then, the more elastic *quartier bleu* method of applying the uniform system has come into prominence, and in some districts the tendency now is to replace the selection system where possible by this modification of the uniform system, except in forests treated primarily as protection forests.

Among the more important mountain forests worked under the selection system in France may be mentioned the silver fir and spruce forests of the Jura and Vosges, the silver fir, beech, and mountain pine forests of the Pyrenees, and the silver fir, spruce, larch, and cembran pine forests of the Alps. The treatment of larch in conjunction with pasturage in the Alps can scarcely be regarded as properly regulated selection working, as the forest is open and park-like, and the grazing interferes with regeneration. The only broad-leaved species worked under the selection system to any extent in France is beech, generally in mixture with silver fir.

In Germany rough selection fellings were practised at least as far back as the Middle Ages. According to Bühler,[1] the oldest mention of a departure from the then commonly practised selection fellings was in 1495, when the cutting of annual coupes was prescribed in the Landesordnung of Württemberg. Bühler quotes Seckendorf (1799) as stating that selection fellings were still common in many places in Germany at the end of the eighteenth century, but that the woods were being ruined thereby. At the present day the selection system, in regulated form, is practised only to a limited extent in the state forests of Germany. It is, however, frequently

[1] Op. cit., p. 564.

practised in small private and village forests, chiefly of silver fir and spruce. Recent statistics show that 10·1 per cent. of the forest area of Germany is treated under the selection system, the percentage being 2·4 for broad-leaved and 7·7 for coniferous forests. In Austria the selection system is common in small private properties in the mountains; in state forests it is worked chiefly for protective purposes at the higher elevations, only dead, dying, and windfallen trees being removed.

In Switzerland the unregulated selection fellings of former days resulted in the serious deterioration of the forests, and the terms *furetage* and *jardinage* fell into disrepute, with the consequence that selection fellings came to be largely superseded by clear fellings in the early part of the nineteenth century. The indiscriminate planting of pure spruce under the clear-cutting system in turn led to the condemnation of that system and its replacement by more natural methods. At the present day the selection system is much favoured in Switzerland, but it is now practised in a highly systematized form having little resemblance to the rough selection fellings which ruined the forests in the eighteenth century.

In England the selection system has long been practised in the beech forests of the Chiltern Hills, but in too many cases the fellings have consisted of cutting out the largest and best trees and leaving the smaller and weaker ones. In many cases the woods have been overworked and brought to a poor condition, with the result that attention is now beginning to be directed towards the abandonment of selection fellings and the introduction of the uniform system.

The problem of working and regenerating the extensive mixed forests of the tropics, in which often only one or a few species are saleable out of a large number, is a very difficult one. In forests of this type rough selection fellings have generally been the rule, a felling cycle being adopted and a minimum exploitable girth being fixed. The constant removal of the best trees of the most valuable species, and the comparative or entire lack of any effort to secure regeneration, must in time reduce the value of forests worked in this way and cause a diminution of future supplies of valuable timber. In India primitive selection fellings of this kind have been in operation for many years, not only in the tropical forests but also in the temperate forests of the Himalaya. In the various tropical Colonies a similar form of exploitation has been the general rule down to the present day. Force of circumstances may necessitate the continuance of such fellings for some time to come, but they should at the

best be regarded as only a temporary expedient, to be superseded by more concentrated systems of felling and regeneration. The true selection system of Europe would obviously be inapplicable in the extensive tracts in question. In India and Burma these primitive selection fellings have already been replaced over considerable areas by more scientific systems, and in future this policy is likely to continue wherever circumstances permit.

FIG. 64. Two-storied high forest. Upper story of oak 110 years old raised by sowing acorns along with field crops: lower story of beech 60 years old introduced by underplanting. Spessart, Bavaria.

FIG. 65. Two-storied high forest. Oak and beech with young under story of beech introduced by natural regeneration. Beech seed-bearers will be removed, leaving only oak in upper story. Spessart.

FIG. 66. Two-storied high forest. Scots pine, 100 years old with under story of silver fir 40 years old introduced by line sowings. Forest of Rambervillers, Vosges.

X

TWO-STORIED HIGH FOREST

Fr. *Futaie à double étage*; Ger. *Zweihiebiger Hochwald.*

Two-storied high forest is a form of crop consisting of an upper story with a lower one beneath it, both being of seedling origin. It may be termed an accessory system, since it may originate from various systems, and is not dependent on any particular method of regeneration.

The commonest form of two-storied high forest is that in which a wood, preferably of a light-foliaged species, is thinned heavily when it is approaching or has reached middle age, and a shade-bearing species is introduced artificially as an under story; the two stories are then allowed to grow up, and either they are both felled together or the upper story is removed in one or a series of fellings, leaving the lower one as a self-contained crop.

Two-storied high forest may be adopted for various reasons, of which the chief are: (1) to provide a soil-protective under story to a species which is itself incapable of preserving the fertility of the soil, (2) to enable a sensitive shade-bearing species to be grown under protective cover, (3) to obtain a mixture of species of which one would be outgrown by the other unless given a start, (4) to effect a gradual change of species and of produce, since the standing volume and the yield from thinnings in the lower story increase gradually, until the lower story eventually takes the place of the upper one, (5) to increase production by growing on the same ground two crops of different ages and with different demands on the soil, (6) to furnish substantial early returns by the heavy thinning of the overwood, (7) to provide a soil-protective under story in order to give freedom of action in thinning the overwood heavily without fear of exposing the soil, to allow the best stems to put on light increment and produce large timber.

The last-mentioned idea is frequently put into practice in Germany under the name of *Lichtwuchsbetrieb*. In the plains of Germany there are many examples of mixed woods of Scots pine and beech treated in this way: during the pole stage the Scots pine is thinned and underplanted with beech, and when the latter has developed sufficiently the pine is thinned out heavily to promote light increment. Similar treatment is frequently applied to oak and beech, the latter being introduced as a soil-protection wood in order

to enable the oak to be thinned out sufficiently (see Fig. 64). Good examples may be seen in the Spessart and elsewhere of oak and beech woods in which an underwood of beech is obtained by natural regeneration, after which the overwood is opened out by the removal of the beech seed-bearers and any defective oaks, leaving an upper story of the best oaks to put on light increment (see Fig. 65). In Great Britain larch plantations are not infrequently thinned out at an age of 15 to 30 years and underplanted with beech or shade-bearing conifers. Among coniferous mixtures, a favourite one in continental Europe is an upper story of Scots pine with a lower story of silver fir introduced artificially, often by sowing, after the pine has been thinned out at middle age (see Fig. 66).

In practising two-storied high forest, care is necessary in the first instance to open the upper story cautiously if there is danger from wind, and to continue to thin it from time to time in order to prevent the suppression of the under story. The chief disadvantage of two-storied high forest lies in the fact that damage is liable to be caused to the under story during the thinning or felling of the upper story; otherwise the system is a useful one when applied for one or other of the purposes mentioned above.

XI

HIGH FOREST WITH STANDARDS

1. PRESENT-DAY PRACTICE

General Description. High forest with standards, like two-storied high forest, is an accessory system, since it may originate from various systems, and is not dependent on any particular method of regeneration. It is produced not by introducing a second crop under an existing one, as in two-storied high forest, but by leaving selected stems of an old crop standing over a young crop established as a result of regenerating the old one. These stems, which are known as 'standards', may be retained, scattered singly or in small groups, for the whole or part of a second rotation. Regeneration may be carried out either naturally from seed, or artificially by sowing or planting.

The chief object of this system is to retain selected stems to put on light increment and produce large-sized timber. Sometimes standards of light-demanders such as Scots pine and larch are retained for a time partly for this purpose and partly to act as seed-bearers for the seeding up of blanks during the regeneration of mixed crops under the uniform or other systems. In certain cases standards are retained for a time over regenerated crops, usually in pine forests, to act as seed-bearers in case the young crop should be destroyed by fire.

Standards should be of species of which there is a demand for large-sized timber; for instance, pine was at one time grown in this way for masts of ships. The selection of standards requires care. Trees suddenly isolated are liable to be thrown by wind or in certain cases to become sickly and die. As a safeguard against wind, standards should not only be of wind-firm species but also possess well-developed crowns indicating a good root-system. In some cases it is customary to prepare trees for isolation by selecting and marking prospective standards many years ahead, so that they may receive special attention during thinnings. In order to prevent the suppression of the young crop, standards should have long boles and crowns well elevated above the ground, and the crowns, although well-developed, should not be too heavy or spreading. Beech is generally an unsuitable standard, as it has a heavy crown and is also liable to sun-scorch when suddenly isolated; in Switzerland, however, beech standards with elevated crowns are retained

for a long time over mixed young crops under the irregular shelterwood system, the height of the young crop being the means of protecting the boles of the beech from sun-scorch. Oak is often retained as a standard, but it is liable to become stag-headed and to produce epicormic branches when isolated; in the Spessart it is sometimes customary for this reason to retain a few small branchy beech, if available, round the oak standards as a protection. Among conifers, Scots pine and larch are frequently retained as standards, for which purpose they are more suitable than most species. Silver fir and spruce are unsuitable; both have heavy crowns and the latter is not sufficiently wind-firm.

Where standards are not likely to survive for the whole of a second rotation, it is sometimes customary to concentrate them along the sides of roads, so that they may be felled and extracted without doing damage to the main crop.

Examples. The system is variously applied. In Hesse-Darmstadt it is well exemplified in Scots pine forests with both artificial and natural regeneration. In the Eberstadt forest, for instance, the pine is clear cut under a nominal rotation of 120 years (formerly 100 years) and replanted along with a temporary crop of potatoes, about 8 to 15 standards per acre being retained for a second rotation (see Fig. 68). When the felling comes round again these old standards are felled along with the remainder of the crop, and new standards 120 years old are selected for reservation as before. The standards selected are the best-shaped and soundest trees, suitable for the production of high-class timber; owing to their tall boles and high crowns there is less interference with the main crop than might be expected in the case of so light-demanding a species. In the forest of Isenburg in Hesse-Darmstadt Scots pine is regenerated naturally under the uniform system, the rotation being 120 years, and a few standards are retained for a second rotation.

In the mixed coniferous forests of Germany and Central Europe generally, it is frequently the custom to leave standards of Scots pine and larch over naturally regenerated mixed crops for part or the whole of a second rotation (see Fig. 67).

In the Spessart, when beech and oak are regenerated under the uniform system it is sometimes customary to leave about 10 oak standards per acre to attain large size. Oak standards are also left in some of the French forests, as in the forest of Bercé, after the completion of regeneration under the uniform system.

Disadvantages. Although the retention of standards for a time may be advisable for purposes of completing the regeneration of light-

FIG. 67. High forest with standards. Young crop of silver fir and Scots pine naturally regenerated; silver fir seed-bearers all removed and Scots pine retained. Private forest, Salmbach, Württemberg Black Forest.

FIG. 68. Scots pine high forest with standards, artificially regenerated by planting along with potatoes. Newly planted coupe on left, young crop 10 years old on right. Eberstadt forest, Hesse-Darmstadt.

demanders or as a precautionary measure in case of fire, there is much to be said against high forest with standards as a means of producing large timber. The standards are very liable to be thrown by wind, and in Scots pine forest instances have been recorded of 90 per cent. of the standards having been blown down. Apart from this, if standards are blown down, or if they have to be felled for any reason before the main crop is due for felling, considerable damage may be caused to the latter. Should the standards be required at any time in case of an emergency, or in order to take advantage of exceptionally high prices, they cannot be felled without the risk of causing damage to the main crop: this is equivalent to locking up capital in such a way that it cannot be released without sacrifice. Standards of broad-leaved species are apt to develop epicormic branches which may reduce the value of the timber. In addition, standards may interfere seriously with the development of the main crop, this being particularly the case where their crowns are low or spreading. In England instances may be seen where large oak trees with low spreading crowns have been retained and underplanted, with the result that the young crop is seriously interfered with or killed outright, and the felling and removal of the standards cannot be effected without causing serious damage.

If a certain proportion of large-sized timber is required, it would seem preferable to set aside a sub-compartment and allow all the trees in it to remain as a self-contained crop for part or the whole of a second rotation, suitable thinnings being carried out to ensure light increment, if necessary with the aid of a soil-protective underwood.

2. THE *TIRE ET AIRE* SYSTEM

The old French *tire et aire* system, which was superseded by the uniform system about the middle of last century, was essentially a form of high forest with standards. Although no longer practised, it is of special interest at the present day, since it produced the high forest crops of oak and beech in France which are now being regenerated under the uniform system, while there are various points of similarity between the two systems which lead to the presumption that the newer system was to a large extent evolved out of the older one. It will therefore be of interest to consider the circumstances which gave rise to the *tire et aire* system, and the chief features of the system itself.

The *tire et aire* system was originally introduced in place of the unregulated selection fellings (*furetages*) under which high forest in

France was generally worked prior to the fourteenth century. These selection fellings, under which single trees were taken out here and there according to age and maturity, were difficult to control, and led to abuses on the part of purchasers, for which reason ordinances were passed which sought to replace this method of exploitation by coupes by area (*aire*). Among the earliest of these ordinances was that of 1318 under Philip V, but probably the most important of them was the Ordinance of Melun (11 July 1376) under Charles V, which may be considered the first *Code Forestier* of France. This ordinance prescribed, among other things, (1) the formation of high forest coupes by area, 10 to 12 arpents (about 12 to 15 acres) in extent, (2) the retention of 8 to 10 standards per arpent (about 6 to 8 per acre) to act as seed-bearers for the regeneration of the coupes, (3) closure of coupes to grazing for a time, in order to protect the regeneration. For more than a century and a half these coupes by area, from which the *tire et aire* system was developed subsequently, were made without any fixed plan as to their situation and outturn; only the location of coupes for sale was decided on from time to time and the prescribed number of arpents was then marked out. The reserve of 8 to 10 standards per arpent was probably only a minimum, and in fact an ordinance of 1516 prescribes the reservation of *balliveaux* in sufficient numbers for seeding purposes.

The want of system in the situation of the coupes led to confusion, and it was therefore decided to make coupes adjacent to each other in regular order, that is, *à tire*. An ordinance of 1544 accordingly prescribed for high forest the *couppe à tire et ayre*, or coupes by areas in regular succession, as had from time immemorial been the custom in coppice. According to the Ordinance of Charles IX, of August 1573, the age of exploitation had to be at least 100 years, and in the case of oak the rotation actually varied from 100 to 300 years. The reserve of at least 8 or 10 trees per arpent was maintained or even increased, advance growth had to be retained and not removed, and the seed-bearers had to be properly spaced. The good intentions of these ordinances, however, were not fulfilled, since about this time, and for more than a century, administrative abuses brought forestry in France to a low ebb; the staff enriched themselves at the expense of the forests, silviculture was neglected, and the good beginning made with the *tire et aire* system came to naught. This was the state of affairs when Colbert came into power in 1661.

Colbert's first act was to suspend all forest exploitation pending

a new reconnaissance by special commissioners appointed to reorganize the state forests. This reconnaissance culminated in the ordinance of 1669, which governed the practice of the *tire et aire* system from then onwards. This ordinance maintained the terms of the 1376 ordinance in prescribing the retention of standards to the number of 10 per arpent, which may be taken as a minimum. It did not prescribe fellings in successive contiguous coupes, but required only that the corner trees of the previous coupe should be used to delimit the next one, the controlling forest officer being left to determine each year the situation of the coupes. It aimed generally at restocking the ruined forests in 100 years, though as a rule the time taken was longer. Generally speaking, the practice followed in regard to the *tire et aire* system from 1669 onwards was as follows:

1. To carry out fellings in successive contiguous coupes in each unit of working, beginning with the oldest portions which were already partially regenerated.

2. To exploit these coupes, already more or less regenerated, reserving the better trees as standards in number variable but at least equal to that fixed by the ordinance or by the particular rules applying to each forest.

3. Where natural regeneration was insufficient, to complete the restocking artificially, as a rule by sowing after breaking up the soil.

4. To clean the young crop, usually about 20 years after the principal felling, at the same time removing dead and dying standards and cutting back damaged saplings with the view of providing straight vigorous shoots; healthy standards were retained for a second rotation in order to obtain large-sized timber.

It is thus evident that the idea sometimes held, that the *tire et aire* system consisted of the clear felling of successive contiguous coupes, retaining 8 to 10 seed-bearers per acre, and leaving the resulting regeneration to look after itself, is incorrect. Such a procedure would not have produced the many fine oak and beech stands existing at the present day, and in fact there are places where the old *tire et aire* standards still remaining after repeated thinnings are so dense that little remains of the under story. It is probable that the fellings were more in the nature of secondary fellings over areas partly covered with natural regeneration, although in some cases artificial regeneration appears to have played an important part, particularly in the case of forests which had reached an open and derelict state by the time Colbert's Ordinance came into force. The appearance of *tire et aire* crops at the present day indicates

that much of the regeneration must have been often of coppice origin. Although the ordinance prescribed cleanings in the young crops, it made no mention of thinnings, and it is impossible to say to what extent, if at all, these were carried out. Records show that thinnings were known and practised in some forests in the sixteenth century. In the eighteenth century they became more general, and among writers of this period Duhamel gave the theory of thinnings almost exactly as it exists at the present day, and recommended making *coupes par éclaircissements* at intervals of 6, 8, or 10 years. Varenne de Fenille, another writer of this period, regarded these operations as an effective means of increasing production by promoting the increment of the most vigorous trees. According to M. R. Potel, in the forest of Bercé in particular the state of the stands more than 150 years old over large areas testifies to the fact that rules of culture must have been practised under the *tire et aire* system similar to those prescribed by Hartig in introducing the uniform system. It is therefore apparent that the uniform system is little more than a development of the old *tire et aire* system, and in fact the chief points in which the former differs from the latter are (1) greater attention to the opening of the canopy for regeneration, (2) removal of all the overwood when regeneration is established, (3) more attention to thinnings to favour the stems of the future and to increase production.

Methods similar to the *tire et aire* system appear to have been followed contemporaneously in other parts of Europe. In 1454 in the Harz Mountains of Germany, mention is made of a departure from the prevailing unregulated selection fellings, in prescribing the retention of a few seed-bearers in otherwise clear-felled areas. In the early part of the sixteenth century there are German records of an attempt to secure spruce regeneration by leaving 10 to 30 seed-bearers per acre, but this attempt was a failure, as the shallow-rooted seed-bearers were thrown by wind.

XII

THE COPPICE SYSTEM

Fr. *Taillis, taillis simple*; Ger. *Niederwald, Ausschlagwald.* The term 'sprout method' is used in the United States. This chapter deals with the system known as 'simple coppice'—a term sometimes used in contradistinction to coppice with standards—together with certain modifications of it, including pollarding.

1. GENERAL DESCRIPTION

Production of Shoots. The coppice system involves reproduction by stool shoots or suckers. When felled near ground-level most broad-leaved species, up to a certain age, reproduce from shoots sent up from the stump (stool). These shoots, known as stool shoots or coppice shoots, arise either from dormant buds situated on the side of the stool at or near ground-level, or from adventitious buds arising from the cambial layer round the periphery of the cut surface. The former are more firm on the stool, and are therefore the more important for purposes of regeneration. As a rule several shoots arise from each stool, with the result that coppice has a characteristically clumped appearance.

As a general rule stool shoots are not produced by conifers, but certain species, notably the redwood of California (*Sequoia sempervirens*), are exceptions to the rule. Among broad-leaved species the age up to which stool shoots are produced, the number and vigour of the shoots, and the vitality of the stools, vary considerably. In the case of most species, stools of large size do not coppice, and hence for the production of stool shoots it is usually necessary to fell trees at an age of not more than 40 years, and in some cases considerably less; the sweet chestnut, on the other hand, coppices to some extent up to an age of 100 years. Among European trees which coppice freely are oak, ash, hornbeam, sycamore, lime, alder, hazel, and sweet chestnut. Beech and birch coppice less vigorously. Aspen, although it produces suckers freely, does not coppice. Oak and hornbeam stools retain their vitality for a long time, lasting through many successive cuttings; those of ash, sycamore, birch, and beech are less enduring. Several kinds of willows are worked as coppice on a short rotation, and respond well to such treatment.

Many tropical and sub-tropical trees coppice with vigour.

Among the *Myrtaceae*, for instance, some species of *Eugenia* and *Eucalyptus* show phenomenal coppicing power. The following figures, based on sample measurements made in 1912 in the blue gum (*Eucalyptus Globulus*) plantations of the Nilgiri Hills in southern India, show the high average yields obtained from coppice areas in these plantations.[1]

Age (Years)	*Mean girth at breast height* (inches)	*Mean height* (feet)	*Volume per acre* (cub. ft. solid)	*Mean annual increment per acre* (cub. ft. solid)
5	9·8	33	1,700	340
10	17·2	61	4,850	485
15	21·4	74	8,050	537
20	23·8	81	11,200	560
25	25·2	85	14,400	576

Fig. 69 shows a coppice area in one of these plantations.

Some species regenerate freely from suckers; examples among trees grown in Europe are white and grey poplars, aspen, wild cherry, common elm, robinia, grey alder and, in the Mediterranean region, holm oak (*Quercus Ilex*). The production of suckers is stimulated not only by felling the parent tree but also by exposing and wounding the surface roots or grubbing up the stump. Many species which regenerate from suckers produce stool shoots at the same time.

Method of Cutting. Coppice is usually cut close to the ground, the stools being given a sloping surface which is trimmed smooth with an axe or adze to prevent water from settling and causing decay. The object of low cutting is to cause the shoots to appear at ground-level and thus to enable them to form independent roots. In the Mediterranean region in dry hot localities the holm oak is sometimes cut below ground-level, the stools being covered with earth. In lands liable to inundation coppice is generally cut several inches above ground-level; this is the common practice with willows on riverain lands and with alder in swampy situations. In India it has been found that under certain conditions cutting close to the ground may result in complete failure, whereas cutting some inches above ground-level results in a successful re-growth of coppice shoots. This has been found by experiment to be the case in some of the sal forests of northern India, particularly in dry localities or dry seasons. The reason is that the stool dries up for a few

[1] 'A Note on the Blue Gum Plantations of the Nilgiris.' *Ind. For. Records*, vol. v, pt. ii, 1913.

FIG. 69. Coppice of blue gum (*Eucalyptus Globulus*) 6 years old. Mean height 41 ft. Volume per acre 3,200 cub. ft. stacked. Nilgiri Hills, S. India.

inches below the cut surface; in such a case by cutting near ground-level the dormant buds on the stool are all killed, whereas if cutting is done a few inches above ground-level the stool does not dry up sufficiently far to affect the buds round the base of the stool.

Season of Cutting. Coppice is usually cut during the season of dormancy, that is, in temperate countries from late autumn to early spring. In general the early spring, before the buds begin to swell, is considered the best time. If the cutting is carried out early in the winter, there is risk of the stools being damaged by winter frost through the separation of the cortex from the wood. In practice the season of cutting is governed to a considerable extent by labour conditions. In the case of oak tan-bark coppice cutting is done during May and early June, after the season of growth has commenced; at this season the bark can be easily stripped and it also contains a higher percentage of tannin than during the season of rest. If the cutting is delayed too long, however, it may result in frost damage in the following autumn, owing to the insufficient lignification of the shoots. Alder coppice in swampy situations is best cut during hard frost in the winter, when the ground is firm. Basket willows are cut at different times according to the class of shoots required (see p. 136).

Experiments have been carried out from time to time to determine the effect of the season of cutting on the production and development of shoots, and the results have been found to vary with species and local conditions. Experiments by R. Hartig[1] near Munich showed that only stools cut up to the middle of June produced shoots sufficiently lignified to withstand the frost of the following winter, and that stools coppiced later than the middle of July either failed to produce shoots until the following spring or remained unfertile. E. Bartel,[2] in experiments carried out near Nancy, found that for oak, hornbeam, and beech the most unfavourable time for cutting was the middle of August, the most favourable being for beech the middle of April, for oak March to May, and for hornbeam March or April; these experiments were conducted on a superficial soil in a somewhat severe climate.

Rotation and Produce. Coppice is essentially a system for the production of firewood and small or medium-sized material up to pole size, but not for the production of large timber. The rotation varies from 1 year in the case of basket willows to 30 or 40 years for the production of posts, poles, and firewood billets of large size.

[1] *Forstlich-Naturwissenschaftliche Zeitschrift*, 1894, p. 428.

[2] *Rev. des Eaux et Forêts*, 29 (1890), p. 310.

Apart from firewood of all sizes from small sticks for domestic purposes to large billets, coppice furnishes, according to the rotation adopted, material for basket-work, pea and bean sticks, hoops, hurdles, fascines, fencing, hop-poles, handles of tools and implements, pit-wood, posts and poles for various purposes, and a large variety of other produce. Among special examples in England may be mentioned oak (rotation chiefly 25 to 30 years) for pit-wood, ash (rotation chiefly 15 to 20 years) for hop-poles, crates, handles of tools and implements, shafts, frames of motor-car hoods, &c., chestnut (rotation chiefly 10 to 15 years) for hop-poles, split fencing and hurdles, and hazel (rotation about 6 years) for hurdles, hedging, bean sticks, crates, and barrel hoops.

At one time oak coppice was extensively grown, both in England and on the Continent, for the production of tan-bark, the rotation varying for the most part from 15 to 20 years. For many years this has been a declining industry owing to the competition of imported tanstuffs, chiefly in the form of extracts, and in consequence the conversion of oak tan-bark coppice to high forest has been in progress for some time past.

Working of Coppice. Coppice is worked by the method of annual coupes by area. The rotation is first determined, primarily on the basis of the size of material required; the area is then divided into annual coupes in number equal to the number of years in the rotation, and one coupe is coppiced each year. Where the maximum annual volume production on a given forest area is of special importance, as in the case of firewood, the rotation of the maximum mean annual increment should be determined. This is done by felling sample coupes of different ages, ascertaining by measurement the volume per acre produced on each, and dividing that volume by the corresponding age; that age which gives the maximum quotient will be the rotation producing the maximum volume outturn per annum over the whole forest. By adopting this procedure the total area required to produce a given outturn of firewood per annum may be reduced to a minimum.

The arrangement of coppice coupes should be such that produce may be removed from a recently felled coupe without passing through other coupes and doing damage. This involves a good system of roads and cart-tracks. In order to economize in roads, long narrow coupes are often formed, with roads running along the ends of them; on hill slopes similar long narrow coupes run vertically up and down the slopes, so that produce may be brought down the slope through the cleared coupe. All material should be

removed before sprouting begins, in order to avoid damage to the young shoots.

After repeated coppicing the stools eventually become enfeebled and die. Blanks caused in this way are filled up with cuttings or seedling plants at the time the coppice is cut, or in exceptional cases by direct sowing. In the case of oak coppice it is customary to replenish with 'stumped' plants, that is, strong nursery plants with the stems cut off near ground-level and the roots pruned. An old English method known as 'plashing' is still employed in the southern counties for filling blanks in coppice. At the time the coppice is cut a certain number of the smaller shoots are cut half through near ground-level, bent over, pegged down, and covered with earth and sods; the production of roots and shoots is stimulated by making longitudinal cuts at intervals through the bark, or by twisting the shoot so as to wound it. If new roots and shoots are successfully produced the layered shoot is severed from the stool after two or three years. Plashing, which should be carried out in the season of rest, succeeds best in the case of species with strong powers of vegetative reproduction, such as lime, ash, and chestnut.

Thinning of Coppice. It is now generally recognized that the thinning of coppice is an important operation, the number of thinnings carried out during the rotation depending chiefly on the length of the rotation, the competition among the shoots, and the market for the produce. In coppice worked on a short rotation thinnings are usually dispensed with, although cleanings are sometimes carried out with the object of removing inferior species. Thinnings have for their object the improvement of the final crop by the removal of congested or defective shoots or those of inferior species, an operation which produces more rapid growth in the shoots retained in the crop; they also furnish produce of different sizes which may greatly increase the financial returns. Thinnings have long been practised in many of the coppice areas of Europe, and their importance is now recognized in India.

The method of executing thinnings in coppice varies. Jolyet [1] recommends that they should be confined to the dominant poles, the smaller shoots being left to protect the soil. On the other hand, thinning experiments described by Émile Mer [2] indicate that the removal of these smaller shoots has a beneficial effect on the growth of those left; the following are the chief results of these experi-

[1] A. Jolyet, *Traité pratique de Sylviculture*, 1916, p. 111.

[2] *Rev. des Eaux et Forêts*, 46 (1907), pp. 321, 353, 398, and 417.

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ments, which were carried out in coppice of hornbeam and lime in the state forest of Champenoux, the object being to compare the rate of growth and production of thinned and unthinned crops:

1. Dominant shoots of thinned clumps from which all the smaller shoots as well as some of the main shoots had been removed showed decidedly superior growth in diameter, height, and volume production, as compared with similar dominant shoots in clumps from which the smaller shoots had not been removed; the money yield was also considerably higher in the former case than in the latter.

2. In general the fewer the number of shoots on the stool the greater was the diameter and height increment produced per shoot.

3. The strongest individual shoots produced the greatest increment.

4. It is probable that there is, per clump, a definite number of shoots corresponding to a maximum production of volume and money; in the experiments in question the number was 4, though the actual number in different cases may be expected to vary with species and local conditions.

5. The thinning of clumps, carried out judiciously and after experiment, would probably increase the yield of coppice considerably.

In other instances the beneficial results of thinning do not appear to be so marked. Measurements recorded in 1916 by A. G. Edie,[1] in regard to teak coppice in Bombay, showed that thinning had little effect on the subsequent growth of the coppice.

2. SPECIAL FORMS OF COPPICE

There are certain forms and modifications of coppice which deserve special mention. Of these the most important are: (1) basket willow coppice, (2) coppice with field crops, (3) pollarding.

Basket Willow Coppice. The coppice system on a short rotation is well exemplified in the case of willows grown for basket-making. The cultivation of osier beds or 'holts' is carried out in many river valleys and alluvial plains in England, and the industry is also an important one in many European countries as well as in parts of the United States of America.

The species most commonly grown in England are *Salix viminalis*, *S. triandra*, and *S. purpurea*, although other species are also cultivated, including *S. amygdalina*, *S. pentandra*, *S. alba* (var. *vitellina* and *cardinalis*), *S. daphnoides*, *S. hippophäefolia*, and other species, with numerous varieties and hybrids. In some districts the term 'osier' is used to denote shoots of the *viminalis* class, with

[1] *Indian Forester*, 42 (1916), p. 157.

open-grained wood and large pith, the harder forms being termed willows, but both terms are often applied indiscriminately.

The cultivation of basket willows is in the nature of an agricultural rather than of a forest industry. The soil on which they are grown may vary from sandy loam or marl to stiff clay, the heavier soils producing shoots ('rods') of closer grain and better quality than the lighter soils. Peaty and undrained waterlogged soil is unsuitable, though by drainage and preparation such soils may often be rendered suitable at least for rods of inferior quality. In preparing land for willow cultivation the usual practice is to break it up in the autumn to a depth of not less than 9 inches, to leave it fallow over the next summer, and to plough it in the succeeding autumn; cuttings are then planted the following spring. Drainage, a very necessary operation, is carried out by means of open trenches usually 2 feet wide and 18 inches deep, the distance apart varying with the consistency of the soil and the amount of drainage required.

'Sets', or cuttings, some 12 inches long, are taken from the large ends of full-length shoots either one or two years old, from two to four sets being cut from each shoot; the bottom ends should be trimmed to a slant and the top ends cut across immediately above a bud. The sets are inserted about 9 inches in the ground, the remaining 3 inches, with at least two buds, protruding. Land ploughed in the autumn may be planted up about the end of February or during March, after the soil has settled down, but in the case of land prepared earlier in the season, planting may be done any time between November and March. In England close spacing is now the general rule, as this produces straight slender rods, reduces the development of side shoots and keeps down weeds; the spacing actually adopted varies from $16'' \times 16''$ to $22'' \times 22''$, or from $16'' \times 13''$ to $22'' \times 18''$, or $24'' \times 14''$. Close spacing, however, necessitates hand hoeing, for which reason wider spacing, with plants $1-1\frac{1}{2}$ feet apart in lines about 3 feet apart, is sometimes adopted to enable horse cultivation to be carried out; this is a common practice in the United States.

Tending operations include regular hoeing to prevent hardening of the soil and to keep down weeds. On land which is not flooded annually with rich silt, manuring with farmyard or artificial manure, such as ammonium sulphate, is necessary. In the first three years blanks are filled up with strong sets of the kind already described; subsequent filling up is done with full-length shoots, which are allowed to grow for two years before being coppiced.

The plantation should be coppiced the first year after it is formed, although the first crop is of little value, the shoots being often branchy and crooked. Thereafter cutting is carried out every year, and the crop increases in quantity and value till about the fourth or fifth year, when full yields begin to be produced. The season of cutting depends on the class of rod required. For the production of 'buff' rods, which are peeled after boiling, cutting is begun before the end of October and completed before all the leaves fall. If 'brown' rods, with bark on, are required, it is carried out in the winter after all the leaves have fallen. If 'white' (peeled) rods are wanted, cutting is delayed until about March, when new sprouting is about to take place. The cutting is done with a sharp knife or special sickle hook.

Although annual coppicing is the rule, it is advisable, if the holt shows signs of exhaustion, to give it a rest for a year to enable it to recover. Some growers make a practice of giving a rest every few years. In such a case, if the area is divided into, say, five equal blocks, one block can be rested each year in turn, so that the actual area cut over annually will be four-fifths of the total, three-fifths consisting of shoots one year old and one-fifth of shoots two years old; the latter are too large for ordinary basket-work, but are in demand for basket-frames and strong hampers, or sticks for basket-work furniture.

A well-tended willow bed, in which blanks are regularly filled up, should last at least 25 years, and there are many which have been cropped for a much longer period. The annual yield from the third year onwards varies, according to locality, species, and other factors, from 3 to 8 tons per acre or even more, a good average being 6 tons per acre.

Coppice with Field Crops. An old practice which has been extensively followed in certain parts of Europe, particularly in Germany, is that of coppice combined with the temporary cultivation of field crops (Fr. *sartage; taillis sarté*; Ger. *Hackwald, Röderlandbetrieb*). Large areas in western Germany—in Hesse-Darmstadt, Westphalia, Nassau, Rhenish Prussia, Bavaria, Württemberg, and elsewhere—are covered with coppice which has been worked under this system ever since the thirteenth and fourteenth centuries.

The coppice consists as a rule of oak for the production of tan-bark, although occasionally there is a mixture of other species, such as ash, maple, hazel, hornbeam, birch, &c.; the field crop most commonly grown is rye, although wheat, oats, and potatoes are also cultivated. The decline in the oak bark industry during

the past few decades has led to the conversion of many of these coppice areas into coniferous high forest, and this is likely to continue in future, with the result that the old practice of *Hackwald* will become less and less prevalent. Economically the practice is an interesting one. It is confined for the most part to tracts situated in somewhat remote hilly country, where the climate is severe and the soil is poor; under these conditions agriculture would be difficult if not impossible without the aid of forestry. As a means of supplementing the local food supply in out-of-the-way districts, where the proportion of land under forest is large in comparison with that under agriculture, the practice of *Hackwald* has proved a great boon to the local population.

The procedure varies in detail. In the Odenwald (Hesse-Darmstadt) the usual procedure is to work the oak coppice on a rotation of 15 to 20 years. The coppice is cut in May, as soon as the bark can be easily stripped; if conversion to coniferous high forest is contemplated cutting may, if desired, be postponed till June, but if coppice is to be continued early cutting is desirable in order to ensure the lignification of the shoots before the following winter. After the utilizable material has been removed and stacked the brushwood remaining is spread over the coupe and thoroughly burnt as soon as it is sufficiently dry, after which the whole area is hoed up by hand; a second hoeing is carried out in October, and the area is then sown with cereals. The crop is reaped with a sickle the following July or August, after which the area is abandoned to the coppice regrowth; if potatoes are grown, however, they are generally cultivated for two successive years before the area is abandoned. It is obvious that the laborious process of hoeing and reaping by hand would not be practicable except in regions where necessity compels the local population to resort to such methods. The burning, while supplying manurial ashes to the soil, does not appear to damage the stools to any extent; it has the effect of causing sprouting low down on the stool, which is advantageous. The stools themselves last many rotations, after which they are replaced by young oak plants with stems cut off near ground-level.

In the Odenwald there is striking evidence that the practice of *Hackwald*, far from exhausting the soil, creates favourable soil conditions. It is remarkable that after the periodical burning of the area and the cultivation of the soil the ground becomes covered with broom, heather being rare or absent; on the other hand, where the coppice is worked in the ordinary way, without intermittent

burning and cultivation, broom is generally absent and the ground becomes rapidly covered with heather, indicating acid soil conditions.

Pollarding. Under ordinary conditions the practice known as pollarding can hardly be termed a forest operation. It consists of cutting the tops off trees with the object of stimulating the production of numerous straight shoots near the top of the cut stem; these are trimmed off periodically at intervals of one or more years to furnish material for basket-work, fencing, hurdles, fascines, &c. Pollarding is carried out most commonly in the case of willows and poplars along the sides of streams and ditches; it is frequently practised in moist meadows, where the pollarding can be carried out at a height sufficient to ensure the shoots being out of reach of cattle. Another practice of a similar kind is the periodical trimming of the shoots which are produced up the boles of certain poplars, a practice which is common in many European countries, particularly along roadsides.

3. ADVANTAGES AND DISADVANTAGES OF THE COPPICE SYSTEM

Since the coppice system possesses special characteristics and presents a distinct contrast to the high forest systems, its advantages and disadvantages can best be appreciated by comparing it with high forest. The following are its chief advantages and disadvantages:

Advantages. 1. It is very simple in application, and reproduction is usually more certain and cheaper than in the case of reproduction from seed.

2. In the earlier stages coppice growth is more rapid, and the poles produced are as a rule straighter and cleaner, than in the case of the same species when of seedling origin; hence where a large outturn of poles or firewood billets of small to moderate size is required coppice is, generally speaking, superior to high forest.

3. Coppice is worked on a shorter rotation than most high forest crops; there is therefore less capital tied up in the growing stock, and earlier returns are obtained, than in the case of high forest, for which reason coppice is particularly suitable for small private properties in places where there is a demand for the produce yielded by it.

Disadvantages. 1. The outturn from coppice consists of material of comparatively small size; there is therefore a limit to its general utility from the point of view of timber production, and its financial

success depends on the existence of a special demand for the produce yielded by it.

2. Coppice tends to exhaust the mineral substances in the soil, particularly if the rotation is short, since it consists largely of vigorous young wood and branches, which absorb more mineral constituents than older wood.

3. Young coppice shoots are particularly subject to damage from frost and from browsing by deer; where frost damage is severe, or where deer are prevalent, the coppice system may have to be ruled out altogether.

4. Aesthetically coppice is less desirable than most forms of high forest, since it is of smaller size and is monotonous in appearance.

It is sometimes held that coppice is unsuitable for hill-sides owing to the risk of erosion and soil deterioration due to the periodical clearing of the area. The risk is probably less than is generally imagined, and is certainly less than in the case of clear cutting in high forest. The stools of coppice on hill-sides possess strong root systems which serve to bind the soil, while the regrowth of coppice shoots quickly covers the ground and checks surface erosion. The protective value of coppice in this respect is well illustrated in some of the chestnut coppice areas on dry hill-sides in Italy.

Owing to its vigorous growth and the comparatively short rotations adopted, coppice is usually considered to be less subject to the attacks of insects and fungi than high forest. In general this is probably true. In France, however, sessile oak coppice has been condemned by more than one writer owing to its greater susceptibility to the attacks of the oak mildew (*Microsphaera quercina*). In the case of the pedunculate oak it is difficult to discriminate between coppice and high forest, since in either case it is much subject to the attacks of this fungus after periods of drought or defoliation by caterpillars.

4. APPLICATION OF THE COPPICE SYSTEM

Coppice is the oldest silvicultural system known. So far as we know it was the only form of forestry systematically practised by the early Greeks and Romans. In Roman times coppice woods, with annual coupes for the production of firewood, vine stakes, and other small material, were termed *silvae caeduae* or *silvae minutae*. Short rotations were adopted; Pliny, in his *Historia Naturalis*, mentions 8 years for chestnut for the production of vine stakes, and 11 years for oak. Basket willows have been grown from very early

times, and at the time of the Roman invasion the Britons were already skilled basket-makers, employing wicker-work for the making of shields and coracles or light boats. In France and Germany coppice was practised during the Middle Ages, mainly for the production of fuel, short rotations being the rule. In Germany the earliest record of coppice is in the year 1359, in the Town Forest of Erfurt. In Switzerland, according to Flury,[1] coppice regeneration was first practised about the sixteenth century, although systematic fellings were not carried out until the end of the eighteenth century.

In Europe at the present day coppice, generally speaking, is of far less importance than it was at one time. In many localities coal has almost entirely supplanted wood as a fuel, and the growing of firewood is unremunerative. Oak bark coppice has lost much of its former importance. In England there are many oak coppice areas which have not been cut for more than thirty years, and are either under conversion to high forest or are awaiting conversion. On the Continent large areas of former oak bark coppice have already been converted, and the conversion of much of the remainder is in progress. Although for the reasons just given the total area under coppice in Europe is steadily diminishing, there are still instances in which coppice gives highly remunerative results in places where there is a special demand for the produce yielded by it. Thus in the south-eastern counties of England chestnut coppice on an average rotation of 10 to 12 years, for the production of spilt fencing, pays well; in Kent it is grown on a slightly longer rotation for the production of hop poles as well as split fencing. In some of the hills of Italy the growing of chestnut coppice, for the production of vine stakes as well as larger material, is one of the most remunerative uses to which the soil can be put, the rate of growth being particularly fast on rich volcanic soil.

In India coppice is a favourite system for the supply of firewood and small poles for local use in scrub forests incapable of producing large trees; it is also frequently applied in forests of sal and other species on small private estates and in the neighbourhood of tea gardens. The eucalyptus plantations of the Nilgiri Hills in southern India are worked with great success as simple coppice for the local supply of firewood. For eucalyptus this system is superior both to high forest and to coppice with standards for the production of high yields of firewood and poles, and is to be recommended for this purpose in subtropical countries where these trees will grow.

[1] *La Suisse Forestière*, 1914.

To summarize, the employment of coppice is restricted to localities where there is a special demand for small produce. Owing to the small capital involved and the quick returns, it is better adapted for private properties than for forests belonging to the state or to large public bodies; state forestry in particular should aim at the production of large timber required for the general good of the community. Under certain conditions, however, coppice working should rightly be undertaken by the State. This applies particularly to localities where regular supplies of firewood or other produce of coppice woods are essential to the welfare of the local population or for the prosecution of some industry, such as mining, and where supplies cannot be ensured without State action: in the British Empire there are many localities answering to this description.

Correct figures showing the percentage of forest worked under simple coppice in different countries are difficult to obtain, since official statistics often fail to discriminate between simple coppice and coppice with standards. Indian statistics for 1923–4 show a total area of 1,858 square miles under simple coppice, representing 3 per cent. of the total forest area under systematic working. This, however, refers only to State forests in British India. There was a steady increase in the area and percentage under coppice during the years prior to 1923–4.

Flury (1914) gives the percentage of forest under simple coppice in Switzerland as 5·1. According to Bühler (1922) the figures are 6·8 per cent. for Germany (more recent figures show 5·1 per cent.), 0·8 per cent. for Austria, and 5 per cent. for Hungary; Bühler's figures possibly include coppice with standards. It should be noted, however, that the area of coppice in most European countries is steadily diminishing, and that the above percentages are probably now too high.

XIII

THE COPPICE SELECTION SYSTEM

Fr. *Taillis fureté, furetage*; Ger. *Geplenterter Niederwald.*

A SYSTEM known as the coppice selection system has long been applied to beech in certain parts of Europe, although it is now less common than it used to be. In France at the present day it is practised chiefly in the Pyrenees, at elevations between 2,000 and 3,000 feet, and to a lesser extent in Savoy and in the Morvan mountains. It may still be seen in some parts of Switzerland, chiefly in the Tessin Canton, and it is common throughout the Balkan Peninsula.

In principle the working of the coppice selection system is similar to that of the selection system in high forest. An exploitable girth or diameter is fixed according to the size of the material required, and an estimate is made of the age at which material of this size is produced; this age determines the rotation, which is divided into a convenient number of felling cycles, and the area is divided into annual coupes equal in number to the number of years in the felling cycle. Each year coppice fellings are carried out in one of the annual coupes, but only shoots which have reached the exploitable size are cut, those below this size being left.

In practice this system varies in detail. In the Pyrenees the most frequent rotation is 30 years, with two felling cycles of 15 years or three of 10 years; a rotation of 27 years, with three felling cycles of 9 years, is adopted in some places. In the Morvan mountains a rotation of 36 years, with four felling cycles of 9 years, is the general rule.

The appearance of beech coppice selection forest is shown in Figs. 70 and 71. The clumps normally consist of shoots of two, three, or four different ages, according to the number of felling cycles in the rotation; these, however, are not always sharply distinguishable, the clump actually consisting as a rule of a few erect shoots of the larger dimensions and a number of smaller shoots, many of these being whippy, flexible, and sometimes even straggling.

At one time it was customary in some places to reserve a few of the larger shoots scattered over the coupe in the form of standards to give seed for the regeneration of blanks caused when the stools died off; this, however, has fallen out of use. Blanks are sometimes filled by pegging down whippy shoots from adjacent clumps and

obtaining reproduction by layers. Beech stools are said to retain their vitality longer under the coppice selection system than under simple coppice.

The beech coppice selection system is generally practised on poor and often rocky ground in hilly country where the trees do not attain sufficient dimensions for high forest, and under severe climatic conditions where young shoots worked under simple coppice would suffer from frost, drought, and snow pressure. Under the coppice selection system the young shoots are better protected from these dangers, as well as from grazing animals, by the cover of the older shoots; apart from this the soil remains permanently covered and it is not subject to periodical exposure as in the case of simple coppice. On the other hand the cutting of the larger shoots is more difficult and tedious, and is apt to damage the smaller ones, while cutting at ground-level is generally impossible. In addition the development of the shoots is poorer than in the case of simple coppice, owing to the suppression which they undergo in the earlier part of their life. Coppice selection forest seldom has a flourishing appearance, and is not to be recommended except in the somewhat special conditions under which it is generally practised.

XIV

COPPICE WITH STANDARDS

Fr. *Taillis sous futaie*, *Taillis composé*; Ger. *Mittelwald*.
In English this system is sometimes known as 'stored coppice' or 'copse', the latter being an old term. American alternative terms which have been proposed are 'composite forest', 'compound coppice', and 'sprout-seedling forest'.

1. GENERAL DESCRIPTION

Coupes and Form of Crop. Coppice with standards consists of two distinct elements: (1) a lower even-aged story treated as simple coppice, and (2) an upper story of standards forming an uneven-aged crop and treated as high forest on the principle of the selection system. The coppice is termed the underwood and the standards the overwood. The object of the standards is to provide a certain proportion of large timber, to furnish seed for natural regeneration, and in certain cases to afford protection to the coppice against frost. Coupes are formed exactly as in the case of simple coppice. The rotation of the coppice is fixed according to requirements, and the area is divided into as many annual coupes as there are years in the rotation. As each annual coupe in turn becomes due for felling, the following operations are carried out in it:

1. The coppice is clear-cut as in the case of simple coppice.
2. A certain number of the existing standards are reserved for at least one more coppice rotation, and the remainder are felled.
3. A certain number of new standards equal in age to the coppice, and preferably of seedling origin, are reserved; these are approximately of the same age as the coppice, having arisen from natural seedlings appearing, or from plants introduced artificially, at the time the coppice is cut.
4. Blanks caused by the death of stools or by the removal of standards are filled up for the purpose of ensuring a future supply of both coppice and standards; if natural seedlings are not present in sufficient quantity, plants of the desired species are introduced artificially.

If these operations are repeated regularly for several coppice

FIG. 70. Beech coppice selection system. Clump with shoots of different ages: large stem in centre about to be felled. E. Pyrenees.

FIG. 71. Beech coppice selection system. General appearance. E. Pyrenees.

rotations of r years, then a coupe about to be felled should consist of coppice aged r years together with standards aged 2 r, 3 r, 4 r . . . years, and a number of young prospective standards aged r years. In other words, the rotation of the standards is a multiple of the coppice rotation. If it is decided to retain standards for a maximum of 4 coppice rotations, then as soon as the felling has been carried out there will remain on the ground standards aged r, 2 r, and 3 r years, those 4 r years old having been felled along with the coppice, and those r years old having been newly reserved. This is shown diagrammatically in Fig. 72, while Figs. 73–5 show the appearance of coppice with standards in different stages. It should be

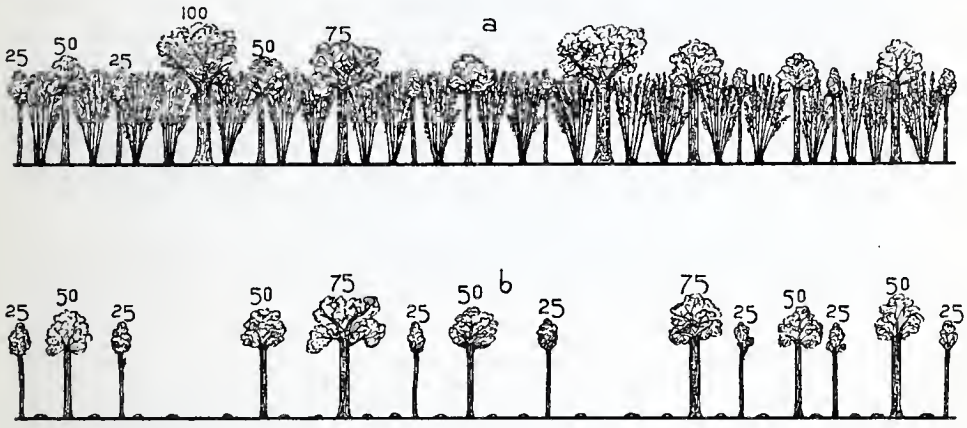

FIG. 72. Coppice with standards. *a*, immediately before cutting ; *b*, immediately after cutting. Rotation of coppice 25 years ; rotation of standards 100 years. Numbers denote ages of standards.

noted that the standards have shorter boles and a larger proportion of branchwood than trees grown in close-canopied high forest. This is particularly the case where the rotation of the coppice is short; with long coppice rotations the boles of the standards are usually free from side branches to a greater height.

The arrangement of coupes to facilitate extraction is carried out as in simple coppice (see p. 132). On the continent of Europe it is sometimes customary to arrange the coupes so that fellings proceed from south to north or from west to east, or in directions intermediate to these, in order to shelter the young coppice against cold northerly to easterly winds.

Species. The underwood in coppice with standards generally consists of a mixture of species; in England these include oak, ash, hornbeam, beech, Spanish chestnut, sycamore, field maple, hazel, alder, birch, lime, elm, cherry, sallow, and aspen, the last-

named regenerating from suckers. Areas of pure underwood of some extent, particularly of oak, ash, Spanish chestnut, or hazel, also occur. Strong light-demanders are less suitable as underwood than species capable of standing a certain amount of shade.

Standards should be of species sufficiently valuable to compensate for the loss of increment in the coppice. They should consist preferably of species with light crowns elevated some distance above the ground; coppice has a better chance of developing under such trees than under trees with heavy and low crowns. From this point of view ash, poplar, cherry, robinia, and birch are among the most suitable species, although the last-named is somewhat short-lived and is not generally of sufficient value. Many broad-leaved species are actually grown as standards. In Europe oak is the commonest standard tree. In England most of the older standards in particular consist of oak, owing largely to the fact that this tree was at one time extensively grown in this manner for ship-building timber, which required large branches with natural curves and bends for the production of 'compass timber' and 'knee pieces'. In recent years oak has suffered much from the attacks of the oak Tortrix moth, and large numbers of standards have been killed out. Beech, although occasionally grown as a standard, is not well suited for the purpose; apart from its heavy crown it is liable to sun-scorch if suddenly isolated. Light-foliaged conifers, particularly larch, make suitable standards.

Classification of Standards. The following English, French, and German terms are commonly used to denote the several classes of standards:

	English	*French*	*German*
Standard of 1 rotation	Teller	*Baliveau, Baliveau de l'âge*	*Lassbaum, Lassreis Lassreitel*
„ „ 2 rotations	2nd class standard	*Moderne*	*Oberständer*
„ „ 3 „	1st „ „	*Ancien (de 2e classe)*	*Hauptbaum*
„ „ 4 „	Veteran	*Ancien (de 1ère classe)*	*Alter Baum, Altholz*
„ „ 5 or 6 rotations	——	*Vieille écorce (de 2e ou 1ère classe)*	——

Standards of the various classes can generally be distinguished by their size, particularly if the coppice rotation is a long one, but if the overwood is composed of several species with different rates

FIG. 73. Coppice with standards. Coppice just cut, and standards reserved. Standards chiefly oak: beech standard in foreground. Forest of Louviers, France.

FIG. 74. Coppice with standards. Young coppice 4 years old. Tintern, England.

FIG. 75. Coppice with standards. Hazel coppice 10 years old with standards of oak and ash. Tintern, England.

of growth this may be a matter of some difficulty. Where there is more than one species in the overwood it is permissible to adopt different rotations for the different species, should their respective rates of growth or longevity demand it, or should the size of material required in the case of each differ appreciably. Thus in the Town Forest of Rastatt in Baden, with a coppice rotation of 25 years, the rotations adopted for the standards are oak 125 years, ash 100 years, birch, alder, and hornbeam 75 years, poplar and robinia 50 years.

Distribution, Reservation, and Removal of Standards. It is usual to fix approximately the total number per acre of standards of all classes to be reserved at the time the coppice is cut. More rarely the volume per acre to be reserved is laid down, this varying with different qualities of soil: as a rule this is applicable only where the crop consists mainly of standards, and approaches selection high forest in character. The number or volume of standards to be reserved depends on the relative importance of the overwood and the underwood. Every additional standard means a corresponding reduction in the outturn of coppice; hence by fixing the number of standards an approximate ratio can be maintained between the outturn of timber and that of smaller material. As a general rule between 20 and 40 standards per acre of all classes are reserved; with more than 40 the coppice, unless strongly shade-bearing, is relegated to a secondary position.

Attempts have been made to maintain the balance between coppice and standards by ascertaining the average space occupied by the crowns of standards of each class, and using the total crown space per acre as a measure of the relative importance of the standards; thus if coppice and standards are to be of equal importance, theoretically the total crown space of the standards should occupy half the area, though actually a good deal will depend on the shade-bearing capacity of the coppice. In practice this method is not so reliable as it might appear, owing to the number of different factors which operate.

As a rule the standards are scattered singly over the area, but sometimes they are concentrated in groups distributed amongst the coppice, or in belts with intervening belts of coppice, an arrangement which produces a larger proportion of clean timber in the standards.

In order to ensure sustained yields, attention has to be paid to the correct age distribution of the standards. Just as in the case of the selection system, allowance should be made for mortality

among the immature standards or for their removal on silvicultural grounds; for instance, for every ten to twenty tellers reserved only one or two may survive to become standards of 4 rotations. The rate of mortality will vary under different conditions, and the average for any locality can be determined only by experience. As an example, assuming that 40 standards per acre are to be maintained, the proportion of these, immediately after the coppice is cut, might be somewhat as follows:

Rotation	1	2	3	4
Number of standards per acre	20[1]	12	8	[4][2]
		40		

[1] Just reserved. [2] Just removed.

Standards for reservation are generally marked with a ring of paint at breast-height, and all trees and coppice shoots not marked are felled. If there is any risk of fraudulent felling special precautions are taken, such as the serial numbering of the standards, the preparation of a descriptive list, and the hammer-marking of the trees at breast-height and also near ground-level. In Belgium a method adopted to prevent fraud is to mark only the tellers with paint, as they are of comparatively little value, and then after the coppice is cut to place hammer marks on the standards to be felled.

The selection of standards for reservation, termed 'storing' in England, should take into account (1) the average number of standards per acre to be reserved, (2) their distribution over the area, (3) the selection of good straight sound specimens of the best species with well-developed but not too spreading crowns, and (4) the maintenance of a correct proportion of classes. The felling of standards is not confined to those which have reached the exploitable age; it includes also the removal of younger standards which are dead, moribund, diseased, or otherwise undesirable, and it may even extend to the removal of sound standards which are in excess of requirements. In exceptional cases even standards which have reached the prescribed exploitable age may be retained for another coppice rotation if they are of specially fine quality and are likely to increase materially in value. It is not always possible to find suitable standards distributed evenly over the area; the prescribed number per acre should therefore be regarded rather as a general average than as a hard and fast figure applying to each acre of forest. Some authorities advise reserving more than the

accepted number almost without limit, if good standards can be found. This, however, ignores one of the main objects of the system, which is to supply a certain proportion of small material; if the object is to produce as much large timber as possible then coppice with standards should be abandoned in favour of high forest. In France it is sometimes the custom to reserve a larger number of standards along the forest boundaries, as a protection against strong and dry winds, and near roads and tracks, in order to reduce the cost of extraction as well as for aesthetic reasons. Where frost damage is severe, it is sometimes the custom to reserve a large number of tellers to protect the young coppice shoots from damage; as soon as the risk is past these tellers are thinned out to the required number.

Standards should, if possible, be of seedling origin, since coppice shoots left standing for a long time tend to become unsound at the base. Where there is a deficiency of seedling trees, however, it may be necessary to reserve selected coppice shoots as standards; these should be chosen if possible from young stools with few shoots on them. Suckers are preferable to coppice shoots, owing to the absence of any wound at the base.

Standards should be felled and removed immediately after the coppice is cut, in order to avoid damaging the young coppice shoots after sprouting takes place. For this reason if oak standards are stripped for tan-bark, this should be done during the spring before felling takes place, the barked trees being left standing until the following winter.

Tending Operations. These comprise cleanings and thinnings and, where necessary, the pruning of standards. Early cleanings include the removal of inferior species, weeds and climbers which are threatening coppice shoots and seedling plants, and also the removal of coppice shoots which are interfering with seedling plants required for the future supply of standards; the latter is an important operation owing to the more rapid growth of the coppice.

Thinnings among the coppice shoots are carried out in the manner already described under simple coppice. In addition, thinnings include the freeing of young prospective standards from coppice shoots which threaten them as well as the removal of dead and dying standards and those whose removal may be otherwise desirable, in so far as this can be done without serious damage to the crop. The pruning of standards may also be carried out with the object of producing clean boles. This operation includes the removal of epicormic branches, which sometimes appear after the

coppice is cut, and other small branches; the removal of large branches may induce decay.

Where young standards are reserved in specially large numbers for the protection of the coppice against frost, these standards require to be thinned out, when the coppice is free from danger, to the number ultimately required; this may be carried out in one or more operations.

2. SPECIAL FORMS OF COPPICE WITH STANDARDS

Among modifications of the usual form of coppice with standards two may be specially mentioned: (1) coppice with coniferous standards, (2) coppice of 2 rotations.

Coppice with coniferous Standards. This consists of coppice with an open uneven-aged overwood of conifers worked on the selection system with a felling cycle equal to the coppice rotation. It is exemplified in some of the mixed forests of holm oak (*Quercus Ilex*) and Aleppo pine (*Pinus halepensis*) on the dry limestone hills of the Mediterranean coastal region of France. The oak is worked as coppice, the rotation being as a rule 25 years. The pine, which is subjected to resin tapping, is worked under rough selection fellings with a minimum exploitable girth limit which varies with the locality; the rotation is not fixed, but may vary from 3 to 5 coppice rotations. Natural regeneration of pine is relied on as far as possible, but supplementary sowing or planting is often necessary.

Coppice of two Rotations. This, in a sense a modification of simple coppice, has for its object the production of a certain proportion of large-sized poles in addition to poles of ordinary size. Coupes are laid out and treated after the manner of simple coppice, but at the time the coppice is cut a few selected shoots are left scattered singly over the coupe in the form of standards; these remain standing for a second rotation in order to attain specially large dimensions.[1] Next time the coppice is cut these standards are felled and new standards are selected from among the coppice shoots of one rotation. In some cases whole clumps of coppice shoots are left standing for two rotations.

In France this method appears to have been commoner at one time than it is now. It is still followed in many of the chestnut coppice areas of Italy. Here the ordinary rotation varies from 10 to 30 years, with periodical thinnings beginning at about 6 years, and the produce consists, according to size, of vine-stakes, bean-

[1] A coppice shoot left for a second rotation is termed in French *volière* and in German *Niederwaldüberhälter*, the system being known as *Niederwaldüberhältsbetrieb*.

sticks, posts, and poles, as well as firewood and charcoal; the shoots of two rotations furnish telegraph and telephone poles, railway sleepers, and even timber for sawing.

3. INTRODUCTION OF COPPICE WITH STANDARDS IN IRREGULAR HIGH FOREST

The conversion of irregular high forest to coppice with standards is well exemplified in many of the mixed deciduous forests of India, and the procedure followed may be usefully employed in other countries where a local demand for firewood and small timber has to be satisfied. Forests of the type in question contain trees of various sizes and species. In introducing coppice with standards the coppice rotation is fixed according to requirements and the area is divided into the necessary number of annual coupes, one of which is taken in hand each year. The number of standards per acre is decided on, together with their allotment to size-classes based as far as possible on the estimated average rate of growth in girth or diameter. The standards to be reserved are marked according to this scheme, and everything else is felled.

As an example, assuming that the coppice rotation is 25 years, that the rotation of the standards is 100 years, and that 30 standards per acre are to be reserved, the following table may be taken to represent the distribution of standards over one acre:

No. of coppice Rotation.	*Theoretical age in years.*	*Corresponding diameter-class in inches (roughly estimated).*	*Number of standards to be reserved.*
1	25	up to 8	15
2	50	9–16	9
3	75	17–24	6
4	100	over 24	all felled
		Total	30

This arrangement makes a rough attempt at distributing the standards according to classes at the outset, although an accurate distribution will not be possible until four coppice rotations have passed. If trees of the various size-classes are not available in the required numbers, it may be necessary to allow more latitude in the distribution of the standards among size-classes, and in places even to retain standards above the maximum diameter limit.

4. ADVANTAGES AND DISADVANTAGES OF COPPICE WITH STANDARDS

The following are the chief advantages and disadvantages of the system of coppice with standards:

Advantages. 1. It furnishes material of different sizes in considerable variety, and is therefore suitable for the supply of a local demand for various classes of produce.

2. It furnishes early returns from the coppice, which is a financial advantage.

3. The forest capital is small compared with that of most forms of high forest, and it can be readily increased or decreased without affecting the system, a fact which tends towards elasticity; this is an advantage in the case of private properties.

4. Owing to the cover of the standards the soil is better protected than in the case of simple coppice.

5. Replenishment of blanks is not carried out wholly by means of artificial regeneration, as in the case of simple coppice, but is effected, in part at least, by natural regeneration from seed, which reduces expenditure.

6. Aesthetically it is superior to simple coppice, since clear-fellings are avoided, and the overwood consists of well-developed trees of different sizes.

7. It is a good system for game preserves, owing to the cover afforded by the underwood.

Disadvantages. 1. It is a difficult system to apply correctly: the maintenance of the balance between coppice and standards, and the correct distribution of standards of different classes, are matters of considerable difficulty; the selection of standards requires skill and is a tedious and troublesome operation to carry out amidst a thick growth of coppice through which it is difficult to see any distance.

2. Standards in coppice with standards are more branchy and shorter boled than trees grown in high forest, and consequently yield a smaller proportion of clean timber; under this system the amount of small material, including branchwood, may amount to as much as 75 per cent. of the total outturn, and much of this is fit only for fuel.

3. Coppice grown under standards is generally less vigorous than simple coppice.

4. The harvesting of the produce requires more labour than in the case of high forest for equal volumes of outturn—Huffel puts

it at 4 to 5 times the amount—for which reason the working of this system has become unremunerative in many places.

5. So far as liability to external dangers is concerned, the following may be noted:

(*a*) the coppice suffers from the browsing of deer where these animals are prevalent;

(*b*) young standards suddenly freed from the intervening coppice are liable to be bent or uprooted by wind and snow, although the older standards, owing to their individual development, are wind-firm;

(*c*) smooth-barked standards, when exposed, are liable to sun-scorch;

(*d*) in the abnormal drought of 1907 and 1908 in northern India coppice with standards suffered more than high forest, the standards in particular being killed off by drought owing to the desiccation of the soil which followed the periodical felling of the coppice.[1]

Attempts have been made from time to time to compare the volume outturns from coppice with standards with those yielded by high forest. It is impossible, however, to arrive at a definite conclusion in the matter owing to the lack of comparative figures relating to identical species and localities of a similar character; a further complication is introduced by the fact that differences in the rotation may have a decided effect on the outturn. Statistics are available showing the outturn per acre yielded by high forest and coppice with standards respectively over a series of years in whole countries or specified districts. These show a higher outturn sometimes in the one case, sometimes in the other. Such figures are admittedly unreliable, for apart from the difficulty of making a fair comparison, for the reasons just mentioned, coppice with standards in Europe is confined as a rule to the more favourable localities, whereas high forest is often situated on less productive ground. As a rule, therefore, comparative figures are unduly favourable to coppice with standards.

The question of total outturn, however, is of small importance compared with that of the respective value of coppice with standards and high forest in the general economy of a country. From this point of view high forest is greatly superior in that it furnishes a much higher outturn of timber, as apart from firewood. At the present day firewood and charcoal do not possess the importance

[1] 'A Note on the Causes and Effects of the Drought of 1907 and 1908 on the Sal Forests of the United Provinces.' *For. Bull.* (India), No. 22, 1913.

which they once had, and in many localities they cannot find a remunerative sale; on the other hand everything points to an increased future demand for timber. As long ago as 1872 Tassy[1] estimated that the annual loss to France, by reason of her large areas of coppice and coppice with standards—the latter predominating—amounted to 293 million francs (£11,720,000 nominal). During the war of 1914–18, when enormous demands were made on the forest resources of France, the inadequacy of coppice with standards as compared with high forest was amply demonstrated.

It is now generally admitted, therefore, that coppice with standards is inferior to high forest without possessing the advantages of simple coppice; it is held that if timber is required it should be grown in high forest, while if firewood and poles are wanted simple coppice is preferable to coppice with standards.

5. APPLICATION OF COPPICE WITH STANDARDS

Historical. Coppice with standards, although not so ancient a system as simple coppice, has been practised in one form or another since the Middle Ages. In England there are records of its having been worked since the twelfth century in Melton Constable Park, Norfolk. Later on prescriptions for the reservation of standards appear in the statutes. In a series of statutes for the preservation of woods, which began in 1544 with Statute 35 Henry VIII, c. 17, it was laid down, chiefly in connexion with coppice woods, that twelve standards per acre should be retained. The same prescription appears later, as when in the early part of the seventeenth century James I commanded that in the New Forest 'twelve standels be left in every acre'. In a maritime country like England coppice with standards was of special importance in the days when branchy oak timber was much in request for the construction of naval and other vessels.

On the continent of Europe the system is of very long standing. In France it has been extensively practised since the Middle Ages. In Germany coppice with standards appears to have been practised in some form from about A.D. 600; in those days it was combined with the pasturage of cattle and swine, for which reason the standards consisted of food-yielding trees such as oak, beech, and fruit-trees, while the underwood was cut periodically to furnish fuel. This practice persisted throughout the Middle Ages, and is occasionally seen even at the present day. In the forest ordinances

[1] L. Tassy, *Études sur l'Amenagement des Forêts*, 1872, pp. 165–72.

of Germany there were prescriptions regarding the reservation of standards, an operation which seems to have been carried out in a systematic manner at least as early as the sixteenth century. In the broad-leaved region of Middle Europe this system was at one time far more prevalent than it is now. In Switzerland coppice with standards was practised fairly widely up to the middle of last century, since when large areas have been converted to coniferous high forest, mainly of spruce.

Present-day Conditions. It will be of interest to consider the present-day position of coppice with standards in some of the countries in which it is practised.

Great Britain. Until comparatively recently coppice with standards was the principal system applied to hardwoods in Great Britain. In the days when oak was much in demand for shipbuilding and there was a good sale for firewood the system was a highly profitable one, and it was worked scientifically with attention to the correct distribution of standards. With the industrial development of the country, the more extensive use of coal, and the construction of railways which distributed coal over the country, the demand for firewood, particularly in towns, diminished or ceased altogether; further, with the introduction of iron ships in the middle of last century the demand for oak timber for shipbuilding began to decline rapidly. In consequence the importance of coppice with standards has greatly diminished, and in many places there is little or no sale for the produce. It is not surprising, therefore, that in recent times the proper reservation of standards has often become neglected, and many British woodlands formerly worked as coppice with standards have degenerated into irregular scrub of little or no value. Many private owners hesitate to convert such woods to high forest owing to the cost involved, while others are undertaking conversion with a fair degree of success. So far as State enterprise is concerned, the Forestry Commission has undertaken a considerable amount of conversion of derelict coppice with standards to high forest. In spite of its disadvantages under present-day conditions, the system is likely to continue to some extent on private estates, partly in the form of game preserves and partly to furnish supplies of timber, firewood, fencing, and other small material for estate purposes and for local consumption in rural districts. There are still a number of small local industries dependent on this type of forest.

The latest forest area figures for Great Britain are those obtained from the census of woodlands carried out by the Forestry Com-

mission in 1924. These show the following areas of coppice and coppice with standards combined, the latter forming the great bulk of the area:

	Area in acres.	*Percentage of total forest area.*
England	485,224	29·8
Scotland	8,120	0·8
Wales	35,331	13·9
Total in Great Britain . .	528,675	17·9

France. Of all continental countries France has been the most conservative as regards the retention of coppice with standards. At the present day almost all the private and communal broad-leaved forests, about 35 per cent. of all the forests of the country, and more than half of all the broad-leaved forests, are treated under this system. In France, as in England, coal has superseded firewood to a large extent in towns, though there is still a good demand for firewood in rural districts; coppice with standards has therefore lost much of the importance which it once possessed. Its general application in private and communal forests at the present day is due partly to its utility in supplying local demands for firewood and other small material, partly to a disinclination to face the expense of conversion to high forest, and partly no doubt to popular prejudice. In State forests, on the other hand, it has long been felt that this system is not a suitable one; the duty of the State, it is held, is to grow large timber, the production of small material being left to private enterprise. For this reason in the State forests of France the conversion of coppice with standards to high forest has proceeded actively, with occasional intermissions, for the past 100 years. At the present day it may be said that all State forests formerly worked under coppice with standards either have been converted to high forest or are undergoing conversion if this is at all feasible. In no country can conversion to high forest be better studied than in France, where an elaborate technique has been developed.

Germany. In Germany coppice with standards was at one time far more widely practised than it is now. Since the early part of the nineteenth century the area under this system has diminished steadily, Saxony having led the way in conversion to spruce high forest. In State forests it has now disappeared almost entirely throughout Germany. Recent figures show only 3·8 per cent. of the total forest area under coppice with standards, chiefly in the communal forests of western and south-western Germany.

Switzerland. Since the middle of last century large areas of coppice with standards have been converted to high forest; recent figures show 3·5 per cent. of the total forest area under this system, but the area is steadily diminishing. Coppice with standards, which still plays an important part in private forests, is practised mainly in moist river valleys and near lakes, often on land which is periodically flooded.

India. In India coppice with standards is an important system for the local supply of firewood, house-posts, and other small material for village requirements. It is much practised in forests which are incapable of producing timber of large size, and it is also the system employed in the extensive irrigated plantations of the Punjab. In 1923–4 12 per cent. of the area of State forest under systematic management in British India, representing 6,855 square miles, was worked under this system.

Conditions of Application. Coppice with standards is applicable only where there is a good local demand for firewood and other small produce as well as some demand for larger timber. In general, therefore, it is suitable for private and communal forests of comparatively small size in readily accessible situations, and not for large State forests at a distance from local centres of consumption. In Europe it is regarded as a system suitable for mild climates and fertile or at least moderately fertile soils, the rich alluvial soils of riverain tracts being particularly favourable; it is not adapted for severe climates and poor soils. In India, however, it is generally practised in the poorer types of forest, where conditions of soil and climate are unfavourable for the production of high forest of good quality.

In Europe the economic conditions which once favoured the general employment of coppice with standards have altered, and the system has had its day; the future should see a steady diminution of the area under this system in favour of high forest systems.

The technique of conversion to high forest is described in the next chapter.

XV

CONVERSION OF COPPICE SYSTEMS TO HIGH FOREST

1. GENERAL CONSIDERATIONS

By a conversion is understood a change from one silvicultural system to another.[1] Conversions often involve some temporary sacrifice, which may be far more than compensated by the ultimate advantage of the new system: before a decision is arrived at in regard to any proposed conversion this temporary sacrifice, if any, should be weighed against the ultimate benefits of the new system. The extent of the sacrifice can generally be reduced by a careful adjustment of the length of the conversion period, and by the provision of regular yields during the transition stage. It is unnecessary, in a work of this nature, to consider the many different forms of conversion from one system to another that may arise in practice; in dealing with the individual systems an indication has been given of the manner in which their introduction may be effected, and this should suffice for our purpose. It is proposed, therefore, to deal here only with the conversion of coppice and coppice with standards to high forest, a question to which much attention has been devoted in Europe for some time past. Many different methods of effecting such conversions have been proposed, attempted, or carried through in practice. The methods adopted vary greatly in detail, but they may be classified broadly into two main groups:

1. Conversion primarily by natural regeneration, usually involving the retention of existing broad-leaved species.

2. Conversion primarily by artificial regeneration, usually involving a change to coniferous high forest.

Frequently natural and artificial regeneration are combined, particularly where a mixed high forest of conifers and broad-leaved species is desired.

In deciding on any method of conversion, the first question to

[1] A distinction is sometimes made between a *conversion* and a *transformation*, the former implying a change in the source of regeneration, e.g. a change from coppice to seedling high forest and vice versa, and the latter implying retention of the same source of regeneration, e.g. a change from the selection to the uniform system and vice versa. There do not seem to be sufficient grounds for this distinction, and it is proposed to employ the term *conversion* to a change from any one system to any other.

be considered is whether the existing species are to be retained and led over into the condition of high forest, or whether a change of species is desirable. In the latter case the conversion is usually to coniferous high forest. In France many State forests are being converted by natural regeneration from coppice with standards to high forest of the same species, which is in accordance with the national policy of increasing the supply of hardwood timber of large dimensions. It is generally agreed that this form of conversion is unsuitable for private forests, as it is not a paying proposition: conversion to coniferous high forest, on the other hand, is considered to be well justified on financial grounds. To quote one example, the State forest of Faye de Montrond in the French Jura has been under conversion since 1885 from coppice with standards to silver fir high forest. Taking pre-war rates and values, the forest yielded an average of 17 fr. per hectare (6*s*. per acre) per annum under coppice with standards. During conversion, up to 1914, it yielded the same even after deducting the cost of sowing and planting, while after conversion it was expected to yield 150 fr. per hectare (50*s*. per acre) per annum, as estimated from the returns derived from existing silver fir forests in the neighbourhood.

The question whether to convert to high forest of the same species or to effect a change to coniferous high forest is equally important from the silvicultural point of view. Experience in Europe has shown that conversion to high forest of the existing species is rarely successful except on soils of at least fairly good quality; on the poorer soils conversion to coniferous high forest is likely to give better results. The problem of conversion by natural regeneration, which may present a good many difficulties, resolves itself largely into one of soil factors on the one hand and seeding conditions on the other. For instance, given frequent seed-years, oak regeneration as a rule gives little trouble on the lighter loams and sandy loams. On clays and marls oak seedlings may germinate successfully, but they are liable to be suppressed by beech where this species is present, and special measures may be necessary to keep the latter in check. The difficulty of regenerating oak is intensified if seed-years occur only at long intervals, as in north-eastern France, where many failures resulted from former attempts to convert to even-aged high forest. On the calcareous soils, where beech predominated, conversion to beech high forest gave little trouble owing to the freedom with which regeneration appeared, but on the more fertile clays and clay marls, where oak predominated, many failures resulted owing to the difficulty of securing

oak regeneration, coupled with the competition of weeds and invasive secondary species such as hornbeam, field maple, and birch. In consequence of these failures conversion had to be abandoned last century in several forests, and a return made to coppice with standards.

One of the most important considerations in the actual process of conversion to high forest is that of preventing the coppice regrowth from suppressing the seedling plants of the new generation. On poor soils, owing to the lack of vigour of the coppice regrowth, little difficulty is experienced in this respect after clear-cutting coppice and planting with conifers. On the other hand, where this regrowth is vigorous, intensive cleaning may be necessary; thus on the limestone and loess areas of Baden, the cutting of coppice and planting of spruce has led to so strong a regrowth of quick-growing coppice shoots that the repeated heavy cleanings necessary have proved too costly, and over large areas the resulting crop consists only of a few scattered spruce trees holding their own with difficulty against a mass of vigorous coppice growth. This question of eliminating the competition of coppice regrowth becomes even more acute where natural regeneration is relied on; it has been solved to a large extent under the French method of conversion by leaving the coppice uncut during a preparatory period before starting regeneration fellings (see p. 161).

A system of conversion should take into consideration something more than the mere process of replacing a coppice crop by a seedling crop. From the economic point of view, particularly in the case of private forests, it should aim during the conversion period at a steady money yield not less than that obtained under the coppice system, and an enhanced yield when the conversion is completed or before it is completed.

2. CONVERSION BY NATURAL REGENERATION

Conversion by natural regeneration involves the retention of the existing species, except in the comparatively rare instances in which coppice areas are invaded by species growing outside the area.

The following forms of conversion by natural regeneration deserve special mention:

1. Conversion of coppice with standards
    - i. to uniform broad-leaved high forest
        - (*a*) with a preparatory period of rest;
        - (*b*) by intensive reservation.
    - ii. to irregular broad-leaved high forest by selection.
    - iii. to coniferous high forest.

FIG. 76. Conversion of coppice with standards to high forest by the method of *futaie pleine*: species chiefly oak, beech, and hornbeam. (1) Crop during preparatory period of rest, showing coppice under thinnings. Forest of Haye, France.

FIG. 77. The same. (2) Coppice thinned out: crop ready for seeding felling. Forest of Rambervillers, France.

2. Conversion of beech coppice selection forest to high forest.

Conversion of Coppice with Standards to Uniform broad-leaved High Forest. (Fr. *Conversion en futaie pleine.*) (*a*) **With a Preparatory Period of Rest.** The system which has been most widely practised in France since the latter part of the nineteenth century is one leading up to the uniform system and involving a preparatory period of rest for the coppice before any attempt is made at regeneration. This system was evolved as a result of certain mistakes made during previous attempts at conversion. One of these was to clear-fell the coppice and leave the standards as seed-bearers for natural regeneration, such supplementary planting being carried out as was considered necessary; in this case the cost of keeping down the coppice regrowth and saving the seedling plants from suppression proved to be excessive, while the drastic opening of the canopy did not always result in the natural regeneration which was desired.

It was then realized that instead of being cut, the coppice should be allowed to grow up long enough for the stools to become enfeebled, the coppice shoots being meanwhile subjected to periodical thinnings in order to furnish returns; the idea was to utilize some of the coppice shoots and most of the standards as seed-bearers to afford natural regeneration, and it was rightly anticipated that when the coppice shoots were finally cut the stools would be too feeble to produce vigorous new shoots. Acting on this idea, Lorentz, who was a great protagonist of conversion to high forest, introduced in 1826 a system of conversion in which the coppice fellings were suspended, and the coppice was allowed to grow up over the whole forest at one time instead of only in those portions which would come under regeneration within a definite period in advance. A serious drop in the revenue followed, as the coppice thinnings could furnish only a small return. In addition, had this procedure been continued it would have produced towards the end of the conversion period an excessive accumulation of enfeebled coppice shoots of advanced age, with a corresponding deficiency of good seed-bearers, and there would have been serious risk of a failure of natural regeneration.

Although this mistake caused a set-back to the policy of conversion, and resulted in Lorentz being placed in retirement in 1839, the pupils of Lorentz and Parade, another strong supporter of this policy, continued to develop the methods initiated by their masters, and evolved the system which is substantially that now followed, namely, to allow the coppice to grow up over only a portion of the

area at a time. It was only in the fifth edition of Lorentz and Parade's *Cours de Culture des Bois*, published by Lorentz and Nanquette in 1867, after Parade's death, that the idea of allowing the coppice to grow up over the whole area was abandoned. The present system took definite shape in 1873. Although the details vary according to local conditions, the following hypothetical case will explain how the conversion is generally carried out:

We may assume that the rotation of the future high forest crop is to be 120 years, which may be conveniently divided into four periods of 30 years each. The whole area may be divided into four corresponding periodic blocks; in practice, however, it is generally found preferable to select only one block at a time, the crops allotted to this block being those containing most standards suitable for future seed-bearers. One quarter of the area is chosen as block I; this block is no longer coppiced, but is left for a preparatory period of 30 years (*Période d'attente*) during which the coppice grows up and is subjected to periodical light thinnings (*Coupes préparatoires*) or is left unthinned. Coppicing is continued as usual over the remainder of the forest, but a larger number than usual of the smaller standards is reserved in order to facilitate future conversion. At the end of this preparatory period regeneration fellings (*Coupes de conversion*) are made in block I by opening the canopy gradually in a series of fellings according to requirements; natural regeneration, with such supplementary artificial regeneration as may be necessary, is completed within the 30 years. During the period of regeneration of block I a second periodic block, No. II, representing one quarter of the total area, is subjected to light thinnings for 30 years, the coppice being cut as usual over the remaining half of the forest. This procedure continues for the two remaining periodic blocks in turn until the whole forest has been dealt with.

The statement on p. 163 shows briefly the steps necessary, commencing, let us suppose, in the year 1901.

Under this system of conversion the various operations are generally carried out as follows:

Thinnings during preparatory period of rest (*Coupes préparatoires*). In the block allotted to the preparatory period of rest only the large *anciens* are felled, and as many standards as possible are reserved, the object being to provide a full complement of seed-bearers and to kill out the coppice. But wherever the cover of the standards is insufficient to kill the coppice, the latter is thinned periodically at intervals of 6 to 10 years, the first thinning being usually carried out during the year when the coppice should

FIG. 78. The same. (3) Seeding felling made; some advance growth on the ground. Forest of Haye.

FIG. 79. The same. (4) After a secondary felling : seedling regeneration on the ground. Forest of Haye.

Periods	*Operations necessary in periodic blocks*			
	I	II	III	IV
1901–1930	Select block I and allow preparatory period of rest. Thinnings in coppice	Coppice to be cut as usual; these blocks not yet selected		
1931–1960	Regeneration fellings	Select block II and allow preparatory period of rest. Thinnings in coppice	Coppice to be cut as usual; these blocks not yet selected	
1961–1990	Cleanings and thinnings	Regeneration fellings	Select block III and allow preparatory period of rest. Thinnings in coppice	Coppice to be cut as usual
1991–2020	Thinnings	Cleanings and thinnings	Regeneration fellings	Allot block IV (remainder of area), and allow preparatory period of rest. Thinnings in coppice
2021–2050	Thinnings	Thinnings	Cleanings and thinnings	Regeneration fellings

ordinarily be cut. The object of these thinnings is (i) to furnish returns from coppice shoots and any standards that may die off, (ii) to remove coppice shoots interfering with the crowns of standards which will be future seed-bearers, (iii) to reduce the number of shoots progressively at each thinning until there are only two or three, or even one, left on each stool; the object of this is to assist in killing out the coppice shoots, since shoots produced after such thinnings soon languish under the cover of the rest of the crop, and the stools lose their vitality.

Regeneration fellings (*Coupes de conversion*). These consist of the usual seeding, secondary and final fellings characteristic of the uniform system. Standards are depended on as far as possible for seed-bearers, since most of the coppice shoots, particularly of oak and beech, are not old enough to provide seed in quantity; some of

the coppice shoots, however, may also be utilized as seed-bearers. The seeding and secondary fellings are made cautiously in order to prevent a vigorous regrowth of coppice. In the seeding fellings the canopy is raised by the removal of coppice shoots giving low cover; large standards, which form the best seed-bearers, are carefully retained. Groups of advance growth are encouraged by removing the cover from over and around them. The gradual opening of the canopy generally encourages the regeneration of beech at the expense of more light-demanding species such as oak, and it may be necessary in places to cut the beech back.

Tending operations in regenerated crops. These consist of cleanings in the younger crops and thinnings later. Cleanings have to be carried out with great care owing to the necessity for assisting seedling regeneration against a regrowth of coppice shoots.

Figs. 76 to 80 show successive stages in this method of conversion.

Conversion of Coppice with Standards to Uniform broad-leaved High Forest (cont.). (*b*) **By intensive Reservation.** This method of conversion, known in France as the method of *balivage intensif*, or Aubert's system, is a modification of the usual French system just described, and was elaborated by M. Aubert in the forest of Écouves (Orne) in France with the object of effecting two improvements on it, namely (1) to increase the early returns in material and money, and (2) to shorten the time required for completing the whole scheme of conversion.

Under this system each annual coppice coupe, as its turn comes round for the usual coppice felling, instead of being clear-cut is treated under *balivage intensif*, that is to say, a number of the best coppice shoots and seedling standards, from 500 to 600 per hectare (about 200 to 240 per acre), or even more if available, are retained to form the future high forest crop. As far as possible the older standards (most of the *anciens* and the badly shaped *modernes*) are removed, and the smaller ones (*baliveaux* and the better *modernes*) are retained; coppice shoots, if retained, are thinned out as a rule to one per stool. Subsequent operations consist of periodical thinnings beginning about 20 years later, followed subsequently by regeneration fellings when the coppice crop is not less than 60 years old, that is, not less than 30 years after the *balivage intensif*: as a rule, however, the average age of the crop is a good deal higher, since care is taken to select areas for regeneration which contain a good proportion of the larger standards for seeding purposes.

Periodic blocks are not fixed ahead. Areas for conversion to high

FIG. 80. The same. (5) Young converted pole crop of oak and beech 30–40 years old; first regular thinning recently made. Forest of Haye.

FIG. 81. Conversion of coppice with standards to high forest by Aubert's method of *balivage intensif*. Species chiefly oak and beech. Coppice just cut; standards and some isolated coppice shoots reserved. Forest of Écouves, France.

FIG. 82. Conversion of oak bark coppice to coniferous high forest with the aid of temporary field crops. Young Scots pine plantation 5 years old with oak coppice regrowth. Odenwald, Hesse-Darmstadt.

forest are selected according to the state of the crop. If there are many standards of the right sizes conversion may be begun, but if not, the crop is kept under coppice with standards and the number of standards retained is gradually increased so that a larger number of them may be accumulated. Crops under conversion generally contain many coppice shoots isolated and allowed to grow up, the necessary density of the crop being thus secured: such coppice shoots in time assist in providing seed for regeneration purposes.

The chief difference between the method of *balivage intensif* and the usual French method described above lies in the fact that in the former the thinning out of the coppice is carried out drastically at the beginning of the conversion period, whereas in the latter it takes place gradually throughout the period. Under *balivage intensif* the thinning out of the coppice to one shoot per stool gives the crop a somewhat open appearance (see Fig. 81), but the canopy closes up satisfactorily after about 10 to 15 years.

On good soil this system has worked well provided the standards retained are mainly *baliveaux* and *modernes*; where many *anciens* are retained the results have not been so good, owing to the amount of room taken up by the large standards. On inferior soils the results are poor, for which reason conversion to coniferous high forest by artificial means is carried out in preference.

Conversion of Coppice with Standards to irregular broad-leaved High Forest by Selection. (Fr. *Conversion en futaie claire*, or *Conversion en futaie pleine par bouquets*.) This system was adapted by Huffel from the treatment followed in some of the private forests in the Ardennes, and has been tried experimentally in the Forest of Amance, near Nancy, since 1907. The main object of developing it was to find some system of conversion under which the regeneration of oak might be effected in regions, such as north-eastern France, where seed-years occur only at long intervals and natural regeneration is a matter of great difficulty. Under such conditions, particularly on compact clay soils where weeds tend to spring up in quantity, attempts at conversion to even-aged high forest have resulted in numerous failures; hence the necessity for devising a system of conversion which will take advantage of such regeneration as may appear in any part of the forest as a result of partial seeding.

The system is one of conversion by means of selection, preferably by groups, the object being to free groups of seedlings, or if necessary scattered seedlings, wherever they appear. Frequent return to the same spot is an essential feature of the system, and hence a

fairly short felling cycle—say 15 years or less—is adopted. Fellings go round the whole forest once during each felling cycle, the standards being opened out and the coppice thinned in order to free any existing oak seedlings and to provide sufficient light for further natural regeneration; at the same time badly shaped and damaged oak seedlings are cut back. The fellings include the removal of dead and dying, badly shaped and otherwise undesirable stems. The same operations are carried out during succeeding felling cycles, the fellings becoming less drastic on each successive occasion; the result is that a selection forest, as far as possible by groups, is developed. Cleanings in the young crops are carried out at short intervals, say every 5 years, and planting is done in areas where regeneration fails.

The chief advantages of this system are (1) that conversion proceeds steadily with a fairly constant outturn from the beginning, owing to the absence of any period of rest, (2) that advantage is taken of partial or sporadic seeding. In the Forest of Amance the treatment has resulted on the whole in a large increase in the quantity of young oak, although regeneration is somewhat poor in the more unfavourable situations. The intensive work required in cleaning out coppice shoots over seedling reproduction might render this system inapplicable over areas of large size.

This system does not differ essentially from that known as the method of *traitement varié*, which has been practised for more than half a century in some of the State and communal forests of the Vosges. Conversion takes the form of an intensive reservation of trees of all ages, usually of valuable species, this reservation varying in character according to the state of the crop. The even spacing of the reserved trees is a secondary consideration, the main object being to retain the best trees of all sizes, oak where possible, and at the same time to encourage promising seedling regeneration by freeing it where it exists: in making openings for this purpose, over-mature or otherwise undesirable trees are removed where possible. Regeneration fellings in different stages—seeding, secondary and final—together with selection fellings, and also thinnings in pole crops, may all proceed side by side in the same compartment; hence the term *traitement varié*. The work is regularized by fixing a felling cycle to ensure that each area is revisited at suitable intervals. The resulting crop is of an irregular character.

Conversion of Coppice with Standards to Coniferous High Forest by Natural Regeneration. In the Vosges and Jura there are many examples of the invasion of coppice with standards by natural seed-

lings of silver fir from adjoining woods and the establishment of these seedlings in such quantity as to effect conversion to silver fir high forest by the aid of cleanings in favour of the fir. Such conversions have actually been carried out in several forests, including Châtelneuf, la Fresse, Champagnole, and others. The process of conversion by natural regeneration is applicable only to special cases in which coniferous seed-bearers are already present in the neighbourhood.

Conversion of Beech Coppice Selection Forest to High Forest. The conversion of beech coppice selection forest to high forest is secured by allowing the shoots to grow up until they seed. A seeding felling is then made by cutting out all the straggling shoots and leaving the erect ones; the latter are removed subsequently by successive fellings, leaving seedling regeneration on the ground.

In the Pyrenees instances may be seen of natural regeneration of silver fir springing up in abundance in beech coppice selection forest towards the upper limits of the beech zone, where it meets the silver fir zone. Some of the beech forests are thus becoming converted naturally to forests containing a large mixture of silver fir.

3. CONVERSION BY ARTIFICIAL REGENERATION

Where conversion of coppice or coppice with standards to high forest is carried out by artificial regeneration, it involves as a rule a change to coniferous high forest; exceptions occur, however, as in portions of the Tintern woods, Gloucestershire, where it is proposed to convert to broad-leaved high forest by artificial means. It may be noted that coniferous crops raised on ground previously occupied by broad-leaved species are exposed to the risks of attack by the honey fungus (*Armillaria mellea*), which occurs as a saprophyte on stumps of broad-leaved trees.

Conversion by means of artificial regeneration can usually be carried out either (1) by clear-cutting, or (2) under a shelter-wood, or (3) by groups. Combinations of these methods are also practised.

Artificial Conversion by Clear-Cutting. This, the simplest form of conversion, is analogous to the clear-cutting system in high forest, and involves the complete clearance of the coupes followed by artificial regeneration. It is specially adapted for the introduction of hardy light-demanders such as Scots pine and larch, or for quick-growing species like Douglas fir in mild sheltered situations. This is the commonest method of conversion to high forest practised in Great Britain. The chief risk lies in the danger of suppression of the young plantations by coppice regrowth, for which reason it is

better adapted for poor soils where regrowth is feeble than for fertile soils where the coppice grows up vigorously.

Conversion is effected by cutting and regenerating each year either the whole of each annual coppice coupe as its turn comes round, or only a part of it. During the conversion period returns are derived at first solely from the coppice coupes, and subsequently also from thinnings in the new crop: after conversion they are derived from thinnings until the oldest portions of the new crop reach maturity. In certain cases the coppice is subjected to a period of thinnings before clear-cutting is carried out, as in some of the Tintern woods.

As a rule artificial regeneration is carried out by planting and not by direct sowing, owing to the necessity for bringing the plants as quickly as possible out of danger of suppression from coppice regrowth. The plants are introduced in the spaces between the stools, and regular spacing is rarely possible. In England the idea is gaining ground that it is generally preferable to adopt a wide spacing, say an average of not less than 7 feet, and to allow the coppice regrowth to fill the intervening gaps; this is particularly desirable where beech is present in the coppice. Careful cleaning of the coppice regrowth is necessary in the earlier years of the plantation.

A method followed by the British Forestry Commission in converting coppice with standards, in which the standards have been cut out, is to cut lines about 3 feet wide and 4 to 6 feet apart through the young coppice, if it is not more than three years old. In these lines conifers or hardwoods are planted, and the coppice shoots are cut back on either side until the plants are safe from suppression. With fast-growing conifers such as Douglas fir and larch this method is successful, but with slow-growing species the cost of keeping down the coppice shoots is somewhat high.

In conversions to high forest in Switzerland last century a method frequently employed was to grub up the stumps of the cleared coppice and grow temporary field crops before planting conifers.

Direct sowing as a means of regenerating cleared coppice is possible only on the poorest soils, as in some of the oak bark coppice areas of Germany. Successful results have been obtained in degraded coppice areas on pasture lands on the poorest parts of the upper and middle red sandstone in the Heidelberg forest, Baden, the species employed being Scots pine. In other parts of the same forest attempts have been made to convert cleared coppice by means of broadcast sowings of spruce, larch, Scots pine, and silver fir, but the subsequent cleanings have proved unduly costly.

Conversion of oak bark coppice in Germany. The German system of coppice combined with agriculture, known as *Hackwald*, has already been described (p. 136). The decline in the oak tan-bark industry has led since about 1880 to the conversion of much of the oak coppice treated under this system to coniferous high forest, chiefly of Scots pine and spruce. The procedure commonly followed is to cut the coppice, peel the bark, and remove the produce in May and the first half of June, and then to burn the debris completely and to hoe the ground once in the summer and a second time in the autumn. Cereal crops, chiefly rye, are sown in October and reaped the following July or August. Next spring the conifers are introduced, Scots pine by sowing in hoed lines 1 metre apart or by planting seedlings one year old, and spruce by planting transplants. The Scots pine is generally concentrated on south and west aspects owing to the danger of snow damage on northerly and easterly slopes. Only occasionally are the conifers introduced at the time the rye is sown. Where spruce is introduced, the coppice is allowed to grow up with it for a rotation in order to obtain another yield of bark, but in the case of Scots pine the coppice shoots have to be kept down in cleanings, although a certain number of good stems are retained to form a mixture. Fig. 82 shows a young pine plantation formed under this system.

Conversion after a period of thinnings. Portions of the Tintern woods are in process of conversion from coppice with standards to high forest. Poor coppice with standards, particularly that containing much hazel in the underwood, is clear cut once for all and replanted with conifers. Otherwise both coppice and standards are thinned periodically for a time before being felled, in order to produce material large enough for pit-props. Pure oak crops, which grow poorly when opened out, are thinned at most twice, then felled on reaching pit-wood size, and replanted with conifers. Oak and beech crops are thinned regularly, beginning at an age of 25 to 35 years, at successive intervals of 8, 10, 12, or more years, the intention being eventually to clear-fell them and to replant in some places with conifers, in others with oak, beech, and other hardwoods. The thinnings, both of the coppice and of the standards, are on the first occasion light, and consist largely of the removal of birch and other inferior species, beech being always carefully retained; subsequent thinnings become successively more drastic. Although the object of these thinnings is mainly an economic one, namely, to increase the outturn of pit-props, there is also a silvicultural advantage in postponing the final cutting of

the coppice, as this has the effect of diminishing the reproductive power of the stools and therefore lessening the cost of keeping down coppice regrowth.

In France the usual method of conversion to Scots pine high forest is to subject the coppice to thinnings during a preparatory period of rest, as in the case of conversion by natural regeneration, and then to clear-fell and sow up with pine.

Artificial Conversion under a Shelter-wood. In continental Europe conversion by artificial regeneration under a shelter-wood is frequently applied in the case of sensitive shade-bearers such as silver fir. In Great Britain Douglas fir and Sitka spruce have been introduced with complete success by this means in places where their introduction on cleared areas resulted in numerous losses owing to frost damage. Experience in Great Britain, where planting and not direct sowing is the rule, has shown that the following procedure gives good results:

1. All large standards should be removed before any planting is carried out, since their subsequent removal causes great damage to the plantation; large gaps created thereby may, if desired, be filled up with light-demanders such as larch or Scots pine.

2. The remaining standards and the coppice should be thinned before planting; the thinnings may, for economic or other reasons, be spread over a period of years and repeated at intervals before any underplanting is done.

3. Underplanting of the thinned coppice and standards should be carried out with shade-bearers only, a fairly wide spacing—such as 8 feet by 8 feet to 10 feet by 10 feet for Douglas fir—being adopted.

4. Subsequent cleaning of the coppice shoots should be gradual and not too drastic; species like Douglas fir and Sitka spruce frequently develop better under the light shade of thinned coppice than in the open, provided that the leaders are not whipped. Hence it is usually sufficient to cut off the tops of the coppice shoots where they threaten the leaders of the conifers, any sudden removal of the coppice being avoided for protective reasons; beech in particular should be retained.

In France, particularly in the Vosges and Jura, there are some good examples of successful conversion of coppice with standards to high forest of silver fir, with or without spruce, by artificial regeneration under a shelter-wood. The procedure commonly adopted is that already described for conversion with a preparatory period of rest (p. 161), the coppice being allowed to grow up for

a time before the crop is opened out for regeneration. When the old crop is opened out in seeding fellings, silver fir is introduced, usually by patch sowings, surplus plants from the patches being used subsequently to fill gaps; spruce, which is generally planted and not sown, is used only in gaps of some size, such as those created by the removal of large standards. The cover under which silver fir is introduced should not be too heavy, and should be well elevated above the ground. A certain amount of natural regeneration, particularly of beech, is aimed at in order to form a mixture with the conifers. Subsequent operations consist of the removal of the old crop in one or more fellings, together with periodical cleanings and refilling of gaps with conifers. In some cases the silver fir is introduced some time before the crop is opened out in seeding fellings, and while the coppice is still in the period of rest; in this case the coppice is subjected to fairly heavy thinnings immediately before the introduction of the fir.

Artificial Conversion by Groups. A method of conversion which has been practised to some extent in England is to plant up groups of moderately shade-bearing species such as spruce and Douglas fir in gaps created by felling standards and thinning out coppice. The gaps are subsequently widened at intervals, as in the group system, and further planting of conifers is carried out round the original groups; in time the groups of conifers join up and regeneration is thus completed over the whole compartment. The resulting crop is slightly uneven-aged. This method of conversion is adopted for protective purposes in situations exposed to wind. It has proved successful from the protective point of view, though the scattered nature of the fellings and subsequent cleanings make it somewhat troublesome and costly in practice.

XVI

COMBINATIONS OF SYSTEMS

A COMBINATION of systems implies the application over the same area of two or more different forms of felling and regeneration in close connexion with each other. It does not include the application of different systems on separate self-contained areas under the same general scheme of management, if the different systems are worked independently of each other. For example, in a tract of hilly country the higher ridges might be worked under the selection system, for protective reasons, the bulk of the area under some even-aged high forest system, and the outer fringes under coppice with standards for the supply of local demands; this would not constitute a combination of systems. In a combination of systems the different forms of felling may take place either simultaneously, as when group and uniform fellings are carried out at the same time, or consecutively, as when regeneration is started by means of uniform fellings and completed subsequently by means of strip fellings passing over the same area.

Generally speaking, if there is no special difficulty in securing regeneration, and if the conditions of the locality permit of it, one definite well-recognized system is always preferable to a combination of systems. The latter tends to complicate working and control, and may lead to serious lack of continuity when changes of managers occur. Nevertheless difficulty in securing regeneration, or complications due to mixtures of species or to frequent changes of soil, aspect or species, may lead to special measures being taken to secure regeneration by every means possible, whether by groups, strips, uniform fellings, clear fellings or otherwise. The almost diagrammatic application of the uniform system over large areas in many of the oak and beech forests of western France is due to a great extent to favourable climatic conditions and the facility with which natural regeneration can be obtained. On the other hand, in the coniferous forests of central Europe, where conditions are less favourable, combinations of systems are frequently met with, such as group with uniform fellings often followed by strip fellings, together with clear fellings with artificial regeneration in the case of storm-broken patches.

In countries and types of forest in which silvicultural systems

have not yet reached such a high state of development as they have in many parts of Europe, and in which problems of regeneration have not yet been fully solved, it may be impossible to lay down definite rules for the conduct of fellings and regenerative operations; in such cases combinations of systems afford the latitude which is necessary if there is to be a reasonable chance of success. The term 'concentrated regeneration fellings' is a convenient one to adopt in the case of a combination of fellings of various kinds carried out with the object of regenerating definite areas within a limited period of time.

XVII

CHOICE OF SYSTEM

The choice of a system for adoption in any given locality involves a careful study of the conditions applying to that locality. The factors to be taken into consideration fall for the most part under two main heads, silvicultural (including protective) and economic. These are sometimes directly antagonistic to each other, so that although a system may be entirely suitable from the silvicultural point of view, it may be inapplicable owing to its economic disadvantages, and vice versa. The more important factors which influence the choice of a system are (1) conditions of regeneration, (2) conditions of growth, (3) nature of terrain and soil, (4) protection against external dangers, (5) personnel and labour, (6) nature of produce required, (7) economic considerations, (8) transport conditions, (9) questions of rights, (10) aesthetic considerations. Factors Nos. (1) to (4) are primarily silvicultural and protective, and Nos. (5) to (8) economic. These factors may be considered in turn, with a few examples.

Conditions of Regeneration. Since coppice systems are limited to those species which coppice successfully, we may confine our attention to regeneration from seed. Where conditions of seeding and germination are specially favourable, systems involving natural regeneration over large coupes may be employed with success, as in the case of the uniform system in the oak and beech forests of W. France, or the clear-cutting system with natural regeneration in the maritime pine forests of the Landes. Where these conditions are unfavourable or variable, systems involving regeneration over smaller units of area are indicated: thus where the seeding is sporadic or irregular, the selection or irregular shelter-wood systems would give better results; or, where the sun exercises an adverse influence on natural regeneration, Wagner's *Blendersaumschlag*, or some shelter-wood system with a long period, may be employed. Under one and the same system the character of the seed influences the form of the seeding felling, which should be more open in the case of light winged seeds than of heavy seeds. In the case of woods which have been rendered derelict through faulty treatment, and contain few good seed-bearers and many weed-covered blanks, systems involving natural regeneration are usually out of the question, and the clear-cutting system with artificial regeneration may be the only possible system to adopt.

Conditions of Growth. Light requirements, rate of growth, and other factors influence the choice of a system in relation to individual species or mixtures. The selection and irregular shelter-wood systems favour shade-bearers against light-demanders. Strong light-demanders are best adapted for the clear-cutting system, the clear-strip system or some short-period shelter-wood system, with very open seeding fellings. Two-storied high forest allows of two species of different rates of growth being grown together provided the species of slower growth is a shade-bearer.

Nature of Terrain and Soil. The clear-cutting system should be avoided on land subject to erosion, landslips or avalanches, in water catchment areas, and in places where the soil is liable to deterioration if exposed; the most suitable systems for such places are those which afford continuous protection to the soil, such as the selection system, the irregular shelter-wood system, or two-storied high forest with a soil-protective under story. On rocky or precipitous ground, where regeneration takes place only in occasional pockets of soil, the selection system is indicated. The soil, in affecting the choice of species, may thereby affect the system adopted; for instance, basket-willow coppice is grown on fertile alluvial soils, while on poor sand and gravel which supports Scots pine, some short-period system, or the clear-cutting system, is indicated. In Europe coppice with standards is generally confined to soils of at least moderately good quality.

Protection against External Dangers. In regions subject to storms the uniform system is usually considered unsuitable owing to the risk involved in isolating single trees, particularly of shallow-rooted species: the group system may also be ruled out owing to the danger involved in creating numerous gaps. In Europe the measures taken to counteract storm damage include the adoption of uneven-aged systems, or the wedge system, or the strip or clear-cutting systems with fellings proceeding against the prevailing storm direction. Where snow damage is prevalent, uneven-aged systems, such as the selection or irregular shelter-wood systems, are considered safer than even-aged systems. Damage by frost and drought is guarded against by adopting some shelter-wood system, or strip fellings proceeding from north to south: two-storied high forest also enables a sensitive species to be grown under protective cover. The clear-cutting system involves undue risk in the case of sensitive species. Experience in India has shown that coppice with standards is more subject to damage by drought than high forest. Where deer are prevalent coppice may be out of the question. So

far as insect damage is concerned, the clear-cutting system may be inadvisable in places where clearings tend to encourage the multiplication of injurious insects, or it may be practised with a special arrangement of coupes (p. 6). Fire risk may necessitate the leaving of standards as insurance trees (p. 42); the question of fire risk in selection and even-aged forest has been discussed on p. 114.

Personnel and Labour. Simplicity of working is a great advantage from the point of view of management and control. In this respect the clear-cutting and simple coppice systems stand out by themselves, because they entail no marking of trees for felling or reservation, and require the minimum amount of skill on the part of the manager. If correctly applied, the selection system is probably the most difficult of all systems, while the marking of standards over coppice is tedious and by no means easy if carried out correctly. In the case of the various systems of successive regeneration fellings in high forest, the skill necessary varies a good deal with the ease with which regeneration can be obtained. In general the short-period systems are simpler than the long-period systems; in the former the work is more concentrated, and the supervision of fellings and of cultural and tending operations is thus facilitated. Among the short-period systems the group system is more difficult to control than any of the other systems owing to the scattered nature of the fellings and centres of regeneration. In skilled hands elasticity of working, up to a point, is a good thing, but in unskilled hands it may lead to serious mistakes.

From the psychological point of view short-period systems, in which the aim is to regenerate definite areas within a limited time, have an advantage over long-period systems, the importance of which should not be overlooked. Short-period systems, in which the manager can see the results of his work, promote a sense of responsibility and joy of accomplishment which cannot be stimulated to the same extent by systems in which the regeneration of an area is spread over a period covering the term, even under the most favourable conditions, of two or three managers. The selection system is the most unfavourable of all systems in this respect.

So far as labour is concerned, simplicity and concentration of work are alike advantageous. The clear-cutting system requires no special skill, and no precautions are necessary to avoid damage to young crops during felling, whereas under the selection and irregular shelter-wood systems the reverse conditions are met with. Under the latter systems great care is necessary to avoid damage to groups of young growth during felling and extraction, particularly on steep

slopes, and the wood-cutter is frequently hampered by irksome rules and by the fear of incurring penalties in case of damage to the growing stock ; this, combined with the discomfort of working among dense and often wet thickets, makes the uneven-aged systems more unpopular from the labourer's point of view than the even-aged systems, and particularly the clear-cutting system. Among high forest systems, so far as avoidance of damage during felling and extraction is concerned, next to the clear-cutting system the wedge and strip systems are the most favourable. As regards the amount of labour required per unit of outturn, coppice with standards requires more and the clear-cutting system with natural regeneration less than any other system.

Nature of Produce Required. So far as the demand for produce is concerned, coppice may be sharply distinguished from high forest; the former is indicated where there is a special demand for firewood or hardwood poles of small to moderate size, and the latter where the demand is primarily for large timber or for coniferous pulpwood or poles. Coppice with standards is suitable for meeting a mixed local demand for firewood together with poles and a certain amount of timber of larger diameter. So far as high forest systems are concerned, if the demand is for clean cylindrical timber of good quality, the more even-aged systems are preferable to the more uneven-aged ones; the former also yield a larger quantity of poles from thinnings, and are therefore indicated where there is a demand for this class of produce, including pulpwood and mining timber. The trees produced by the selection system are generally more tapering and branchy, and the growth of the timber is more uneven, than in the case of even-aged systems. In Europe the selection system is frequently employed in small private or village forests where there is a local demand for timber of various sizes. Where straight clean timber of specially large size is required, high forest with standards and two-storied high forest are useful systems. Where coniferous forests are grown solely for pulpwood or mining timber, the clear-cutting system with artificial regeneration is often the only one feasible, since trees producing material of the size required are frequently too young to furnish natural regeneration. This system is also commonly applied where a complete change of species is desired, but if the new species is a sensitive shade-bearer it may be introduced artificially under one of the shelter-wood systems or as an under story in two-storied high forest.

Economic Considerations. From the economic point of view concentration of work has a decided advantage over diffusion of

work; it cheapens the cost of felling and extraction, of cultural and tending operations, and of supervision generally. From this point of view the clear-cutting and simple coppice systems are the most favourable and the selection system the least favourable of systems. Of other high forest systems those with short regeneration periods are more advantageous than those with long periods, since they represent greater concentration of work. Experience in India has shown that a change from selection fellings to concentrated regeneration fellings has usually resulted in a marked rise in the money yield of the forest owing to the reduction in the cost of felling and extraction. Concentration of work may justify the construction of tramways, ropeways, or other works which would be out of the question where the selection system is in operation. Economically the clear-cutting system possesses a further advantage over other high forest systems, in that working costs are reduced owing to the fact that there is no marking of trees prior to felling.

The financial advantage secured by substantial early returns, which is of particular value to private owners, is more marked in some systems than in others. Coppice, and to some extent coppice with standards, have special advantages in this respect, while they also involve a comparatively small outlay of capital. Among high forest systems, two-storied high forest provides substantial early returns from the heavy thinnings carried out at the time the lower story is introduced. Of other systems, the more even-aged systems as a rule furnish early returns from thinnings in greater quantity than the more uneven-aged systems. The clear-cutting system with artificial regeneration may be employed, as in the spruce forests of Saxony, to secure the highest financial returns by adopting a short rotation, though from the silvicultural point of view this may lead to trouble (pp. 18–21).

Transport Conditions. Certain systems can be applied successfully only if there is a good system of roads or tracks whereby produce can be removed without damage to young crops. This applies particularly to systems, such as the clear-cutting or strip systems with horizontal coupes in hilly country, where cutting sections should be bounded by graded roads at no great distance from each other (see pp. 9 and 86 and Figs. 4 and 40). Coppice and coppice with standards in particular require a good network of roads and tracks, since the coupes are generally of small size, and extraction through growing coppice has to be avoided. Where transport conditions are backward, rendering forest tracts somewhat inaccessible, the extraction of anything but large timber may be unremunerative;

in such a case selection fellings may be the only means of working the forests.

Questions of Rights. The existence of rights of user, particularly as affecting the class of produce to be furnished, may influence the choice of a system. In the case of grazing rights, where definite areas have to be closed for regeneration, short-period systems and the clear-cutting system are preferable to long-period systems and above all the selection system, in which regeneration for the time-being extends over a considerable portion or the whole of the forest.

Aesthetic Considerations. From the aesthetic point of view those systems which maintain a continuous forest cover, and particularly the selection system, are preferable to those in which periodical clearings are made, such as the clear-cutting and simple coppice systems. In Europe a belt of forest treated under the selection system is often maintained round the outskirts of towns and villages.

XVIII

CHANGES OF SYSTEM

Cases arise from time to time in which it may be necessary to convert from one system to another, or to introduce a recognized system in a forest hitherto treated under some primitive or faulty method of working. Changes of system may be desirable for various reasons, such as (1) changes in market demands, (2) questions of national policy, (3) failure of the existing system from one cause or another, (4) improvement of communications, (5) advance of silvicultural knowledge, (6) improvement of personnel.

In some cases changes from one system to another involve little or no sacrifice, while in others there may be considerable temporary sacrifice involved. Hence before deciding on any conversion the ultimate benefits to be derived should be carefully weighed against the temporary loss, if any, during conversion, and steps should be taken where possible to minimize this loss (see p. 158). The usual method of introducing systems of concentrated regeneration in irregular forests has been indicated on p. 63. The chief disadvantages of this method are (1) the sacrifice of immature timber in places where this has no market value, and (2) the possible difficulty of obtaining regeneration wherever it is required.

The sacrifice of immature timber can be lessened by adopting a long regeneration period as a temporary measure. Suppose, for example, that the ideal is to adopt a rotation of 120 years divided into six regeneration periods of 20 years each, but the crops are so uneven-aged that they cannot be regenerated in even-aged form without a great sacrifice of immature trees. In such a case we may, as a temporary measure during the first rotation, form double periods of 40 years during which one-third of the area would be regenerated, instead of single periods of 20 years during which one-sixth of the area would be regenerated; the oldest trees would be removed, as far as possible, during the earlier part of the period and the smaller trees during the later part. This would produce a somewhat uneven-aged young crop, but the sacrifice of immature trees in the old crop would be lessened.

In the mixed irregular forests of the tropics, in many of which only a few out of a large number of species are saleable, the introduction of concentrated regeneration will often result in a great

increase in the proportion of valuable species, and the ultimate gain may far outweigh any temporary sacrifice of immature timber.

So far as regeneration is concerned, if natural regeneration cannot be stimulated wherever it is required, it may be necessary to utilize such advance growth as is already present, and to free it wherever necessary; that is, to follow regeneration rather than to endeavour to force it. From this point of view a method proposed by Sir Peter Clutterbuck for the sal forests of northern India is worthy of notice. The sal tree tends to regenerate in even-aged groups and masses, but natural regeneration cannot always be relied on wherever it is required, and the formation of definite periodic blocks may not therefore lead to successful results. Under the proposed method the rotation is fixed and the yield is regulated by volume, based on periodical enumerations. Periodic blocks are dispensed with, but the serial order in which blocks or compartments are to be taken in hand is prescribed, and the fellings are carried out entirely on silvicultural lines, the object being to encourage the development of even-aged groups, patches, and masses of all sizes; the fellings thus take the form of cleanings, thinnings, and improvement fellings, as well as secondary and final fellings, according to requirements. Each year's work closes, when the annual yield has been obtained, at some convenient natural feature or artificial line. This method was devised primarily for forests containing a large proportion of the younger age-classes. It has the advantage of lessening the sacrifice of immature timber while encouraging the natural growth of even-aged groups and masses. On the other hand, it does not tend towards the rapid establishment of a correct proportion of age-classes, though it paves the way for the subsequent introduction of the uniform or other definite system.

XIX

DEVELOPMENT AND CHARACTERISTICS OF HIGH FOREST SYSTEMS

1. DEVELOPMENT OF SYSTEMS

The development of the various silvicultural systems of the present day has been brought about by a combination of silvicultural considerations on the one hand and economic considerations on the other. The former relate to conditions of growth and regeneration, maintenance of soil-fertility, and protection against damage of various kinds; the latter take into account market or other demands, reduction of working costs, and other factors of an economic character.

A study of the history of the various high forest systems affords interesting evidence as to how these systems have arisen. The selection system in its scientific form of to-day is of recent introduction, although it arose from a primitive form of cutting dating from early times. Clear cutting has been practised for some centuries, at first with natural and later with artificial regeneration, but it was only in the beginning of last century that it was systematized in its present form by Cotta. The uniform system has been evolved during the last four centuries or more, although it was first applied in its present-day form by G. L. Hartig rather more than a century ago; there is little doubt that it arose from the now obsolete *tire et aire* system of France or from similar old systems of Germany. Group fellings were systematized by Gayer in the latter part of last century, although they had been practised many years before. The shelter-wood strip system, representing an important modern development, was adapted from the uniform system, while Wagner's *Blendersaumschlag* and the wedge system of Eberhard and Philipp are more recent modifications of the strip system.

It is apparent, from this brief retrospect, that the more modern systems are largely the result of a process of evolution, in the course of which the accumulated experience of the past has been brought together from time to time and systematized by some person of standing, who has generally added original ideas of his own and thus produced a new system. Judging by past experience, there is little reason to doubt that in Europe itself the future will see a steady development of silvicultural systems, which may include the supersession of some of those now in operation by improved systems

based on the results of further research and experience. In other parts of the world, under conditions differing widely from those prevailing in Europe, there is great scope not only for the intelligent application of existing systems but also for the elaboration of new systems.

In continental Europe the present trend of development is manifesting itself in various ways, and some of the ideas which have gained prominence in recent years will be considered in the remaining portion of this chapter.

2. SOME PRESENT-DAY IDEAS

Regeneration. There is at present a preponderating body of opinion in favour of natural as opposed to artificial regeneration, owing partly to the unfortunate experience of Saxony and Switzerland in the matter of spruce plantations. The more recent systems all aim at natural regeneration to the utmost extent, and in practice the skill of a forest officer is not infrequently rated in inverse ratio to the amount of supplementary artificial regeneration which he finds it necessary to carry out. The development of ecology as a science has given a special impetus to the study of the physical and physiological conditions bearing on natural regeneration. In ecological language regeneration fellings are nothing more than a process of stimulating succession of a required kind. In order to achieve success it is necessary to study the conditions under which this can best be effected by a partial or complete removal of the forest cover, resulting in the reduction of root competition, the admission of light, warmth, and precipitations, and the alteration of soil conditions. Modern continental practice recognizes two main forms of natural regeneration in high forest, the one from overhead trees (*Schirmverjüngung*) and the other from the side (*Seitenverjüngung*). In the former seedlings establish themselves under the cover of the old wood, while in the latter they establish themselves in the open. In practice a combination of both, as in the shelterwood strip system, is common. Some writers regard the distinction between the two forms of regeneration as so fundamental that they make it the chief basis of classification of the high forest systems. The prevalence of strip fellings in one form or another, particularly in coniferous forests, is evidence of the popularity of this form of regeneration in many parts of Europe; so much is this the case that an era of strip fellings may be said to have commenced.

Intensive and Extensive Treatment. Another matter which has exercised a profound influence on the development of European

systems in recent years is the policy, under certain conditions, of substituting intensive treatment over small units of area (*Kleinflächenwirtschaft*) for more extensive treatment over large units (*Grossflächenwirtschaft*). The underlying idea is that in European countries the area of forest is limited and cannot be extended indefinitely; hence it is necessary to increase to the utmost extent the production over those areas which are available. This entails the close study of every variation of soil and situation, and intensive working over small units of regeneration. For this reason advocates of intensive treatment hold that systems involving regeneration extending over areas of some size, such as the uniform system, should be discarded in favour of systems involving intensive regeneration over separate small units of area, such as the strip system. They maintain that extensive treatment is successful only where conditions are unusually favourable for regeneration and growth. These contentions are reasonable in countries where forest organization has advanced so far as to make it possible to overcome difficulties of regeneration by highly intensive treatment: otherwise more extensive methods may be unavoidable. From the cultural point of view the intensive treatment of small units may be regarded as the more highly developed form: on the other hand, where conditions are sufficiently favourable there may be distinct advantages in extensive treatment from an economic point of view.

Regularity and Irregularity. There is one important question on which opinions are much divided, namely, that of regularity as against irregularity: the former generally denotes even-aged and the latter uneven-aged crops. The chief arguments on either side have been summarized in dealing with the advantages and disadvantages of the irregular shelter-wood system (p. 76). Advocates of regularity maintain first, that the old crop should not be retained a day longer than is necessary, otherwise it interferes with the free development of the young crop, while the latter is much damaged during felling and extraction, and second, that clean cylindrical stems of even growth are preferable to branchy conical stems. Advocates of irregularity point to soil improvement, natural conditions of growth, and the development of the individual tree as of paramount importance. The solution of this vexed question lies in the adoption of that method which best suits the various local conditions considered in relation to each other, since there is no single system applicable to all conditions. In connexion with irregularity, great prominence has been given in recent years to what is known as the *Dauerwald* idea, which will be explained in the next section.

3. DAUERWALD

Definition. In an article published in 1920 and 1921 under the title *Kiefern-Dauerwaldwirtschaft*,[1] attention was first drawn by the late Dr. Alfred Möller to a new method of treating Scots pine forests. In this paper Möller described the management, over a period of 29 years, of a forest in the estate of Bärenthoren near Dessau in the German State of Anhalt, belonging to Kammerherr Friedrich von Kalitsch, who, himself a professionally trained forester, has been mainly responsible for any success attained by the treatment of the forest.

The term *Dauerwald* may be translated briefly as 'continuous forest', that is, forest treated in such a manner that the soil is never exposed, the forest cover being continuously maintained over every part of the area. Möller applies the term *Dauerwald* in general not to any one particular method of treatment, but to any system not involving clear cutting and the exposure of the soil. Thus he divides the various methods of treatment into two groups, (1) *Dauerwald* methods, in which the soil is never exposed, and (2) clear-cutting methods, in which the soil is exposed for a time before it is covered by a new crop. Among the former, for instance, he would include Wagner's *Blendersaumschlag*, as well as shelter-wood systems in general.

Dr. Dengler of Eberswalde in 1925 proposed the following more detailed grouping of the systems in their relation to *Dauerwald*:

(*a*) The ideal *Dauerwald* form: the selection system.

(*b*) Systems approximating to *Dauerwald*: Wagner's *Blendersaumschlag*, long-period systems such as the Baden and Swiss *Femelschlag*, and two-storied high forest.

(*c*) Systems having little connexion with *Dauerwald*: shelter-wood systems such as the uniform, group, strip, and wedge systems with short regeneration periods producing more or less even-aged crops.

(*d*) The antithesis of *Dauerwald*: the clear-cutting system.

Möller's paper was followed by numerous criticisms, some favourable, some the reverse, and the term *Dauerwald* has enjoyed more notoriety than almost any other term in forestry during recent years. Since the discussions following Möller's paper have centred

[1] *Zeitschrift für Forst- und Jagdwesen*, January 1920, pp. 4–41, and February 1921, pp. 70–85. Reprinted in pamphlet form under the title *Dauerwaldwirtschaft*, 1921. See also *Dauerwaldgedanke*, by the same author (Berlin, Julius Springer, 1922).

mainly round the treatment of Bärenthoren, the following account of it may be of interest:[1]

The Bärenthoren Treatment. The forests, rather more than 1,600 acres in extent, situated on more or less level country at an elevation of about 420 feet, are composed of Scots pine originally raised artificially on old cultivated land: beech has also been introduced on a small scale. The soil is diluvial sand, usually fine-grained and soft, with pebbles and small boulders of flint and granite. The climate is dry, the normal rainfall being about 22 inches: this is due to the fact that rain is intercepted by the Harz Mountains lying to the west of this region. The pine trees are of a race with comparatively short branches and narrow conical crowns, and are obviously more shade-bearing in character than is usual with this species. Seed-years are of frequent occurrence, and natural regeneration springs up in great abundance, not only in this forest but also in other pine forests in the neighbourhood which are not worked on *Dauerwald* principles.

Records of the forest are available since the early part of last century, and these point to the fact that owing to the frequent removal of litter and to over-cutting and general neglect, the state of the crops was at one time extremely poor. These abuses lasted till 1883, when Herr von Kalitsch introduced the treatment with which he has persevered to the present day. It has been claimed that by this treatment the soil quality, as determined by yield tables, has been raised from IV to II, while the stands have improved greatly in health, vigour, and productive power. Möller produces figures showing that whereas the annual cut in 1872 was 21 cubic feet per acre, it rose during the period 1884 to 1913 to an annual average of 47 cubic feet per acre: in addition, the increase in the volume of the growing stock during the period 1884 to 1913, apart from what was removed in the annual cut, was at the rate of 43 cubic feet per acre. The accuracy of these figures has been questioned by several writers. For some years prior to 1923 the outturn averaged about 3 cubic metres per hectare (43 cubic feet per acre) per annum.

The chief features of the *Dauerwald* treatment as applied at Bärenthoren are as follows:

(1) At least 50 cubic metres of *Derbholz* (timber 7 cm. in diameter and over) are maintained permanently on every hectare, that is, 715 cubic feet per acre, so that the soil is never exposed by clear felling.

[1] The particulars given here were obtained during a visit to Bärenthoren in 1923, through the courtesy of Herr von Kalitsch.

(2) The maximum increment possible is aimed at with the minimum forest capital.

(3) The fellings consist of thinnings repeated every two or three years in the same place; until recently they were carried out annually over the whole forest.

(4) There is no rotation and no diameter limit for felling; no tree, however large, is felled if it is still growing vigorously, while on the other hand trees of all sizes are removed if they have lost their vigour or if they are diseased, malformed, or otherwise undesirable.

(5) All tops, branchwood and other debris from the thinnings are left lying on the ground; this material decays in the course of a few years, producing a deep layer of humus which enriches the soil; owing to the water capacity of the decaying wood the soil remains moist and *Hypnum* moss flourishes, with the result that a striking improvement in soil conditions is claimed to have taken place since the introduction of the present treatment; the removal of litter, which was at one time practised, is entirely prohibited.

(6) Natural regeneration is relied on, and as a rule springs up freely wherever light is admitted, the trees producing seed in abundance at an age of 50 years or even less; apart from the *Hypnum* moss already mentioned, which is favourable to regeneration, the soil-covering consists of a little grass and a scanty growth of heather; on the poorest soils beech is introduced, which indicates that even the worst soils are not so excessively poor as has been represented.

(7) The annual yield is not fixed in any way, but a careful record is kept of the outturn of each compartment, and every 10 years a fresh enumeration of each compartment is carried out.

The essence of the *Dauerwald* treatment of Bärenthoren may be said to be constant tending of the soil and the growing stock by means of thinnings repeated at frequent intervals without interruption. Originally raised artificially on open land, the stands in their younger stages were even-aged plantations of pure Scots pine, and were treated much like pine plantations in general, that is, they were kept fairly dense in order to promote clean stems, congested thickets being thinned and wolf-trees removed. Regular thinnings now begin at an age of about 20 years; these, like thinnings in general, aim at encouraging the stems of the future and developing the crowns of individual trees without seriously breaking the canopy. Here the stems of the future, spaced about 6 to 7 metres apart, are marked in advance for future retention, subject to reconsideration if necessary; reference has already been made to the retention on the ground of all brushwood (see Fig. 83).

From about 40 years onwards the treatment differs from that usual in even-aged crops, in that the opening of the canopy is begun, and at each frequently repeated thinning thereafter it is still further opened out rapidly, with the result that in a few years natural regeneration makes its appearance in quantity (see Fig. 84). Regeneration having been secured, the overwood might safely be removed without delay, but this would be contrary to the idea of retaining vigorous stems for the production of increment, and of maintaining not less than 50 cubic metres of *Derbholz* on every hectare. Hence no attempt is made to free the young crop, but the thinnings in the overwood proceed regularly according to requirements, and the young crop has to make its way up as best it can; the fact that the pine here stands more shade than is usual with this species is an undoubted aid in this respect.

At this stage the usual appearance of the crop is that of irregular two-storied high forest, the under story being as a rule uneven-aged and the upper story consisting of vigorous trees in open groups of varying size or scattered singly (see Figs. 85 and 86); these trees have well-developed crowns extending downwards to at least one-third of the total height, and the stumps of felled trees show rapid diameter growth. Where the removal of the overwood has been carried out more gradually and irregularly, a selection type of forest results. Again, a stage may be reached in which there is no large timber left in the stand, the requisite amount of *Derbholz* being furnished by the young crops. This form, which resembles an even-aged pole wood, such as would be produced under the uniform system with a long regeneration period, is not desired, since the aim is to retain as far as possible a certain amount of old wood and to produce an uneven-aged crop. In places the stand has been kept too dense for regeneration until some time after full height-growth has been attained, and then opened out after the manner of the uniform system; the result has been a flourishing even-aged crop of natural regeneration, indicating that the uniform system could be applied with complete success.

Other Examples. The *Dauerwald* idea in one form or another has been applied more or less experimentally in various localities, including Eberswalde, Hohenlübbichow, Freiburg, Barr (Lower Alsace), and elsewhere. In Holland it was introduced in 1890 in the Crown Woods near Breda, and more recently in the woods of the Agricultural College at Wageningen. Again, the principles adopted in conversion from coppice with standards to high forest, under the methods of *futaie claire* and *traitement varié* (pp. 165 and

FIG. 83. Scots pine forest treated as *Dauerwald*, Bärenthoren. (1) Artificially created even-aged crop 37 years old, approaching stage when heavy thinnings are carried out. Note brushwood left on ground.

FIG. 84. The same. (2) Natural regeneration following opening of canopy.

FIG. 85. The same. (3) Early stage in establishment of natural under story; young growth up to 10 years old.

FIG. 86. The same. (4) Overwood 73 years old; irregular natural under story up to 20 years old.

166), are essentially *Dauerwald* principles. In fact, there is no lack of examples of the application of these principles in one form or another.

At Eberswalde the treatment aims at selection forest, but the soil quality, age-class distribution and desired mixture were already satisfactory before its introduction, while the former very moderate estimate of the yield might well account for any increased outturn under *Dauerwald*. The special features of the treatment are rather small gap fellings with artificial regeneration of Scots pine, but the difficulty of tending the small groups of pine has frequently resulted in their failure through suppression and other causes; good results, which are the exception, are confined to favourable soils.

A form of *Dauerwald* described by Forstmeister Seybold[1] was brought into operation in 1900 over an area of some 5,000 hectares of forest, consisting chiefly of silver fir and beech, at Barr in Lower Alsace, and was practised at all events until that province passed into French hands in 1918. The area was worked under a felling cycle of 5 years, the fellings consisting of the removal of suppressed, diseased, and mature trees or groups of trees, and the intensity of cutting varying in each compartment not according to a predetermined yield but according to silvicultural requirements and the state of the market. The result was a forest of the selection type. For such treatment Seybold recommends the formation of compartments averaging not more than 10 hectares (about 25 acres), or, in small communal and private woods, 3–5 hectares (about $7\frac{1}{2}$–$12\frac{1}{2}$ acres): he also urges the abandonment of elaborate calculations for fixing the annual yield, in favour of the determination of the increment by the periodical remeasurement of small permanent sample plots suitably distributed over the area.

Criticisms and Conclusions. In criticizing *Dauerwaldwirtschaft*, it should be remembered that it is not a system in itself, but rather the expression of an idea, namely the abandonment of rigid and artificial methods of forest management and silviculture in favour of a closer adherence to natural laws, with the object of stimulating the factors of healthy growth and increasing the production of the forest. Most of its leading principles—soil improvement, avoidance of clear fellings, tending of individual stems, retention of vigorous trees for the production of increment, &c.—are neither new nor peculiar to it. *Dauerwaldwirtschaft* may be said to include collectively those systems which involve continuous and uninterrupted maintenance of the forest, as opposed to *Periodenwirt-*

[1] *Forstwissenschaftliches Centralblatt* 41 (1919), p. 405.

schaft, by which this continuity is periodically interrupted by clear fellings; it endeavours to secure 'a continuous harmonious co-operation of all factors of growth', and is, in fact, nothing more than one of the many protests which have been made for some time past against the treatment of forests as purely artificial crops, a treatment which gained ground towards the end of the eighteenth century, and led to clear cutting and artificial regeneration on a large scale, often under conditions opposed to the dictates of sound silviculture and in disregard of the reaction between the forest and the soil.

While the general aims of *Dauerwaldwirtschaft* are commendable, and the results achieved at Bärenthoren are undoubtedly successful, yet under less favourable conditions and over large areas management on these lines would run a grave risk of breaking down because it relies to an unusual extent on individual attention, ignores age-class distribution, normality, rotation and yield, and takes no thought for regeneration. The lack of any acknowledged rotation is perhaps of less consequence than might be supposed. Even under some of the recognized systems the rotation may be made somewhat elastic by providing for the retention of vigorous trees beyond the usual time and for the premature removal of unhealthy trees. Actually at Bärenthoren 150 years is regarded as the maximum age ordinarily attainable by vigorous trees, or in other words a maximum rotation of 150 years is implied, though not definitely stated.

Apart from any objection in matters of principle, the Bärenthoren treatment is not without its defects in actual practice. The frequently repeated thinnings are costly, and the difficulty of control and the lack of trained personnel for carrying out the intensive work required were recognized as drawbacks even by Möller. The error of regarding the treatment as being in itself responsible for the success of natural regeneration and for the development and vigour of the trees in that locality has been demonstrated by Dr. Wiedemann,[1] who has made a detailed study of conditions in the Scots pine forests in the neighbourhood of Bärenthoren which have not been worked on *Dauerwald* principles. His investigations have shown that in these forests on similar types of soil the results as regards the maintenance of soil fertility, the development and vigour of the trees, and the success of natural regeneration, are in no way inferior to the results attained in Bärenthoren.

Investigations by Dr. Albert have further shown that owing to the low rainfall the finer soil particles are not washed down; the soil is therefore rich in these fine particles and in organic matter, and is

[1] *Zeitschrift für Forst- und Jagdwesen*, 1926, p. 269.

consequently of better quality than was formerly assumed to be the case. On this account regeneration is unusually prolific, and the success of the treatment is thus connected with exceptionally favourable local conditions.

The ideas embodied in the present-day conception of *Dauerwald*, in regard to continued maintenance of soil-fertility together with maximum sustained production, do not differ radically from those enunciated by the Frenchman Gurnaud in 1879 in a paper explaining the treatment applied by him to the forest of Eperons. These ideas received severe criticism at the time, but were further elaborated by M. Biolley in Switzerland, and were brought to fruition in the intensive form of selection system (*Jardinage cultural*) to be seen in the forest of Couvet and other forests of the Val de Travers. There is, however, a vital difference between Möller's interpretation of *Dauerwald*, which implies the negation of system, and Biolley's *Méthode du Contrôle* (*Jardinage cultural*), which involves the application to the selection system of the most scientific principles of yield regulation yet devised for it.[1] As will be seen from the footnote, Biolley definitely aims at age-class distribution and the establishment of the normal forest, with the view of ensuring sustained yields; Möller, on the other hand, considers these fundamental principles of forest management to be superfluous.

The ideas involved in *Dauerwald* are reasonable enough if they are not pushed too far. Strict regulation, often involving clear-cutting, may be necessary to bring forests which are virgin or depleted or newly created into an organized state, but the subsequent treatment of these forests may have to be modified in order to conform more closely to natural laws. Some supporters of the *Dauerwald* idea, however, have gone so far as to maintain that the ideal of the normal forest, with definite rotation and relations between age-classes, is not essential in forest management, but that the test is the actual production that can be obtained continually; that the

[1] Biolley's *Méthode du Contrôle* is essentially a method of yield regulation, and does not therefore come under consideration here. As it adopts certain *Dauerwald* principles, however, its main distinguishing features may be summarized: these are (1) adoption of the principle of maximum increment with minimum growing stock; (2) maintenance of a definite distribution of size-classes, with the object of establishing the normal forest and ensuring sustained yields; (3) formation of small compartments as independent units of working and control; (4) complete remeasurement of the growing stock at intervals of a few years with the view of determining the relation between increment and growing stock, fixing the yield for the next period, and securing the objects mentioned under (1) and (2); (5) abandonment of the idea of an exploitable girth, and selection of trees of any size for felling.

ideal of the normal forest may have been necessary at a time when European forest management was occupied in building up organized forests and providing sustained yields, but that new methods and ideals are now possible. Hence the attempt to swing the pendulum back to irregularity. Under certain favourable conditions, such as small areas, easy regeneration, close and intensive supervision, this may be feasible; otherwise there is grave risk that the pendulum will swing back to a state of chaos. It is impossible, therefore, to avoid the conclusion that whereas it may involve certain principles that are eminently sound, the *Dauerwald* idea cannot be contemplated seriously for practical application if it is dissociated from the accepted principles of forest management.

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